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Edward R.C. Hornibrook

Natural Resources and Energy

Mineral Resources

ISSN 1183-5508

Price $4.50

This report should be referenced in the following manner:

HORNIBROOK, E.R.C. 1991. Glacial dispersion of heavy minerals in the Todd Mountain area, central New Brunswick. New Brunswick Department of Natural Resources and Energy, Mineral Resources, Open File Report 91-11, 145 p.

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GLACIAL DISPERSION OF HEAVY MINERALS IN THE TODD MOUNTAIN AREA, CENTRAL NEW BRUNSWICK

by

Edward R.C. Hornibrook

A senior report submitted
in partial fulfillment of the requirements for
the degree of Bachelor of Science in Engineering

Geological Engineering Program
UNIVERSITY OF NEW BRUNSWICK
Fredericton, N.B.
April 12, 1991

ABSTRACT

This study was undertaken as a pilot project to determine the usefulness of the heavy mineral fraction of tills from the Todd Mountain area of Central New Brunswick in regional mineral exploration and possibly geological mapping.

The results demonstrate that the Todd Mountain horizon and the Trout Lake granite may be readily traced using specific indicator minerals. The Todd Mountain horizon can be delineated using whole garnets and garnet aggregates (coticules). When the combined data from these two indicators is contoured, an excellent correlation exists between the metasedimentary horizon and the contour maximums. Zircon, which is a common accessory mineral in granites, has proven to be a good indicator of the Trout Lake pluton. Although the concentration of zircon in the tills of the area is high, it is still a very suitable tracer mineral for the granitic body.

Fourteen samples contained grains which were optically identified as possible gold or electrum. The gold and electrum may be associated with the Sn, W, and other base metal vein mineralization crosscutting the Todd Mountain horizon. Further investigation is required using electron microbeam techniques to confirm the identifications.

Good correlations were observed between individual element assays reported by Lamothe (1990) and several of the heavy minerals identified in this study, especially garnet and zircon. The relationships were in support of co-geneity rather than elemental enrichment of particular minerals.

Local topography has exerted considerable control on the glacial processes of the area. The topographic lows are characterized by flat evenly spaced contour intervals for the indicator minerals. The topographic highs proved the best opportunity for glacial action to create distinctive dispersal plumes. It is also believed that the ridges may be acting as sites for the mixing of tills as the ice passes over them. This was apparent in the mineral correlations of coticule with whole garnets and clear zircon with zoned zircon.

Actual distances of physical glacial transport may be short. Mineral dispersal plumes may be better suited for geological mapping, rather than mineral exploration, since distinct plumes are on the order of several hundred meters to a maximum of approximately three kilometers.

If the heavy mineral fraction of the tills is to be exploited for mineral exploration, then it is recommended that the survey be carried out on tight, closely spaced grids. Sample grid centers should not be spaced more than 100 to 250 meters apart in order to accurately access dispersal characteristics.

RÉSUMÉ

Cette étude a été entreprise à titre de projet pilote afin de déterminer l'utilité de la fraction des minéraux lourds des moraines de la région du mont Todd, au centre du Nouveau-Brunswick, pour l'exploration minérale régionale et possiblement pour la cartographie géologique.

Les résultats ont démontré qu'on peut facilement établir l'horizon du mont Todd et déceler le granite du Lac à la truite au moyen d'indicateurs minéralogiques précis. On peut délimiter l'horizon du mont Todd à l'aide de grenats entiers et d'agrégats de grenats (coticules). Lorsque les données combinées de ces deux indicateurs sont tracées, une excellente corrélation existe entre l'horizon métasédimentaire et les courbes de niveau maximales. Le zircon, qui est un minéral accessoire courant dans les granites, s'est avéré un bon indicateur de pluton au Lac à la truite. Même si la concentration de zircon est élevée dans les moraines de la région, il représente toujours un minéral de dépistage très indiqué pour les corps granitiques.

Quatorze échantillons renfermaient des particules identifiées optiquement comme particules possibles d'or ou d'or argentifère. L'or et l'or argentifère peuvent être associés à l'étain, au tungstène et aux autres métaux communs de la minéralisation filonienne transversale de l'horizon du mont Todd. Des études plus approfondies à l'aide de microscopes électroniques à microfaisceau sont nécessaires pour confirmer les identifications réalisées.

De bonnes corrélations ont été observées entre les teneurs en chacun des éléments signalées par Lamothe (1990), et plusieurs des minéraux identifiés dans cette étude, particulièrement les grenats et le zircon. Les rapports appuyaient l'affinité entre les minéraux plutôt que l'enrichisement de minéraux donnés en certains éléments.

La topographie locale a exercé un contrôle considérable sur les processus glaciaires de la région. Les dépressions sont caractérisées par des intervalles verticaux plats d'écarts

uniformes des minéraux indicateurs. Les élévations ont aidé l'action glaciaire à créer des panaches effluents distinctifs. On pense également que les crêtes peuvent agir comme sites de mélange des moraines lorsque les glaces les franchissent. Ce phénomène était évident dans les corrélations minérales entre les coticules et les grenats entiers ainsi qu'entre le zircon net et le zircon zoné.

Les distances réelles du transport glaciaire peuvent être courtes. Les panaches effluents peuvent mieux convenir à la cartographie géologique qu'à l'exploration minérale, car des panaches distincts s'étendent sur plusieurs centaines de mètres jusqu'à un maximum d'environ trois kilomètres.

Pour exploiter la fraction des minéraux lourds des moraines aux fins d'exploration minérale, il est recommandé d'effectuer les levés selon des quadrillages serrés et très rapprochés. Les centres des quadrats échantillons ne doivent pas être séparés de plus de 100 à 250 mètres pour fournir une évaluation précise des caractéristiques de la dispersion.

ADDENDUM

SECTION 5.1.7 of this report identifies a mottled yellow to creamy pinkish yellow colored mineral, which possesses extreme reflectance and sectility, as possible native gold and/or a naturally occurring alloy of gold, silver and copper (electrum). Subsequent analysis by scanning electron microscopy (SEM) employing an x-ray energy dispersive system (EDS) and x-ray diffraction (XRD) analysis have determined the substance to be an alloy consisting of tin and lead intergrowths.

Since native tin and lead occurrences have been previously reported, the alloy was not immediately disregarded as a contaminate. The presence of the alloy as inclusions in other minerals provided the primary support for a native metal origin. However, further optical examination of many examples of the substance and its mode of occurrence within the grain mounts, later proved conclusively that it was not of a natural origin, but rather a contaminate introduced during the polished epoxy grain mount preparation process.

ACKNOWLEDGEMENTS

I would like to thank Toon Pronk and William Gardner of DNR & E for providing me with summer employment and supervision during the reduction of the samples.

I would also like to Dr. Bruce E. Broster of the University of New Brunswick for his supervision of the sample analysis, preparation of the written report and for providing additional funding to the project.

The Department of Geology at U.N.B. is thanked for the preparation of the polished epoxy grain mounts, the use of their lab equipment and office space. As well, the Geological Engineering Program is thanked for the use of the program microscope.

Thanks to Dr. L.T. Trembath for suggestions in mineral identification and for use of the x-ray diffraction equipment. Also, thanks to Dr. J.C. White for arrangements to use the scanning electron microscope facilities.

This senior report was funded by the Minerals Branch of the Department of Natural Resouces and Energy, New Brunswick, the Geology Department at the University of New Brunswick, NSERC Operating Grant A1886 to Dr. Bruce E. Broster, and an NSERC University Undergraduate Student Research Award implimented through Dr. J.G. Spray.

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1.0 INTRODUCTION

1.1 PURPOSE

The purpose of this senior report project was to determine the usefulness of data from the heavy mineral fraction of tills from the Todd Mountain area of central New Brunswick, in regional mineral exploration and possibly geological mapping.

The study was intended as a pilot project. It involved many trial and error stages in order to assess the most efficient and practical methods for later work in the region. A literature search of similar studies was an integral part of the project. The "trial and error" steps were not attempts to develop new techniques, but rather to determine which of the existing techniques were most applicable to the study area.

1.2 SCOPE OF PROJECT

The samples used in the study were the remaining sample splits from a previous Geological Survey of Canada (GSC) field study by Lamothe (1990). These were reduced to their heavy mineral fraction through a series of separations involving panning, shaker tables, and heavy liquids (See Appendix I). They were then prepared as polished epoxy grain mounts. Initial mineral identications were made optically. When ambiguities arose identifications were confirmed by x-ray diffraction and/or microbeam techniques. All grain counts were eventually made optically once the mineralogy of interest was confirmed.

One of the main objectives was to determine the approximate nature and length of dispersal trains based on the down-ice concentrations of the heavy mineral below known mineralized sources. The topography of the area was an important consideration in this determination. Several secondary objectives were inherent to this goal. The first was to access the potential of the various heavy minerals as indicators of provenance. The second was to determined the number of grains which had be counted in order to give an accurate measure of the modal abundances of the various heavy minerals in the samples. This was achieved through a statistical analysis of incrementally counted groups. Contour plots were ultimately employed to study the nature and length of the dispersal.

Mineral relationships were investigated by calculation of mineral correlation coefficients between normalized counts of individual mineral types and mineral groups. Further, an attempt was made to relate the observed mineral abundances to the chemical analysis from Lamothe's (1990) study. Correlation coefficients were calculated between normalized heavy mineral modal abundances and the elements analysed for by Lamothe.

1.3 SUPPORT AND FUNDING

This project began in May of 1990. Summer research was performed at the Annex Building of the Hugh John Flemming Complex in Fredericton, New Brunswick. Funding was provided by the Minerals Branch of the New Brunswick Department of Natural Resources and through an NSERC University Undergraduate Research Award.

The polished epoxy grain mounts were prepared by the Geology Department at the University of New Brunswick. The Geology Department also provided office space for the microscope work, access to the departmental x-ray diffraction equipment, and to the universities scanning electron microscope facilities.

The research microscope was provided by the University of New Brunswick Geological Engineering program.

1.4 GLACIAL MATERIALS AND PROCESSES

Till is a geologically young sediment and represents a lithological summation of bedrock units up-ice from a given location. Material from a source unit is transported down-ice to produce a ribbon or fan-shaped dispersal train. A dispersion train is a body of till specifically enriched in debris from a source relative to the till surrounding the train (eg. Coker and DiLabio, 1989; Shilts, 1976; Peuraniemi, 1987).

A knowledge of the nature of glacial dispersion trains in an area is beneficial when conducting mineral exploration. The ability to correctly interpret various lithogeochemical surveys can be greatly enhanced when this information is known.

1.5 HEAVY MINERALS

Many of the economic minerals (cassiterite, scheelite, wolframite, and base metal sulfides) and associated minerals (fluorite, zircon, tourmaline, rutile, ilmenite, garnet, and iron oxides) all share the property of having a specific gravity greater than 2.85 (Einhart et al, 1973). This characteristic places them into a category of minerals known as "heavy minerals".

These minerals are almost all strongly resistant to chemical and physical weathering in the near surface environment. The exceptions are the sulfides which readily oxidize, and scheelite and wolframite which are brittle and disintegrate away early during transport (Luepke, 1984).

Heavy minerals can be useful in the deciphering of till provenance. This is owing to their general durability which permits them to withstand long glacial transport. They are thus capable of reflecting different source areas and are a common and readily studied constituent of tills. (Gwyn and Dreimanis, 1979).

2.0 TODD MOUNTAIN AREA, CENTRAL NEW BRUNSWICK

2.1 LOCATION AND GEOLOGY

The location and geology of the study area are shown in FIGURES 1 and 2. The area consists of metasedimentary and metavolcanic rocks of the Tetagouche group which have been intruded by late Devonian granites. The rocks are in faulted contact with the Magaguadavic slates of Silurian age. (Poole, 1963; MacLellan et al., 1990).

Todd Mountain lies within a thin NE-SW trending band of low grade metamorphosed Ordivician shales and siltstones (Os_1) (FIGURE 2). The Upper Devonian Trout Lake Granite lies to the north of the Ordivician sediments. The

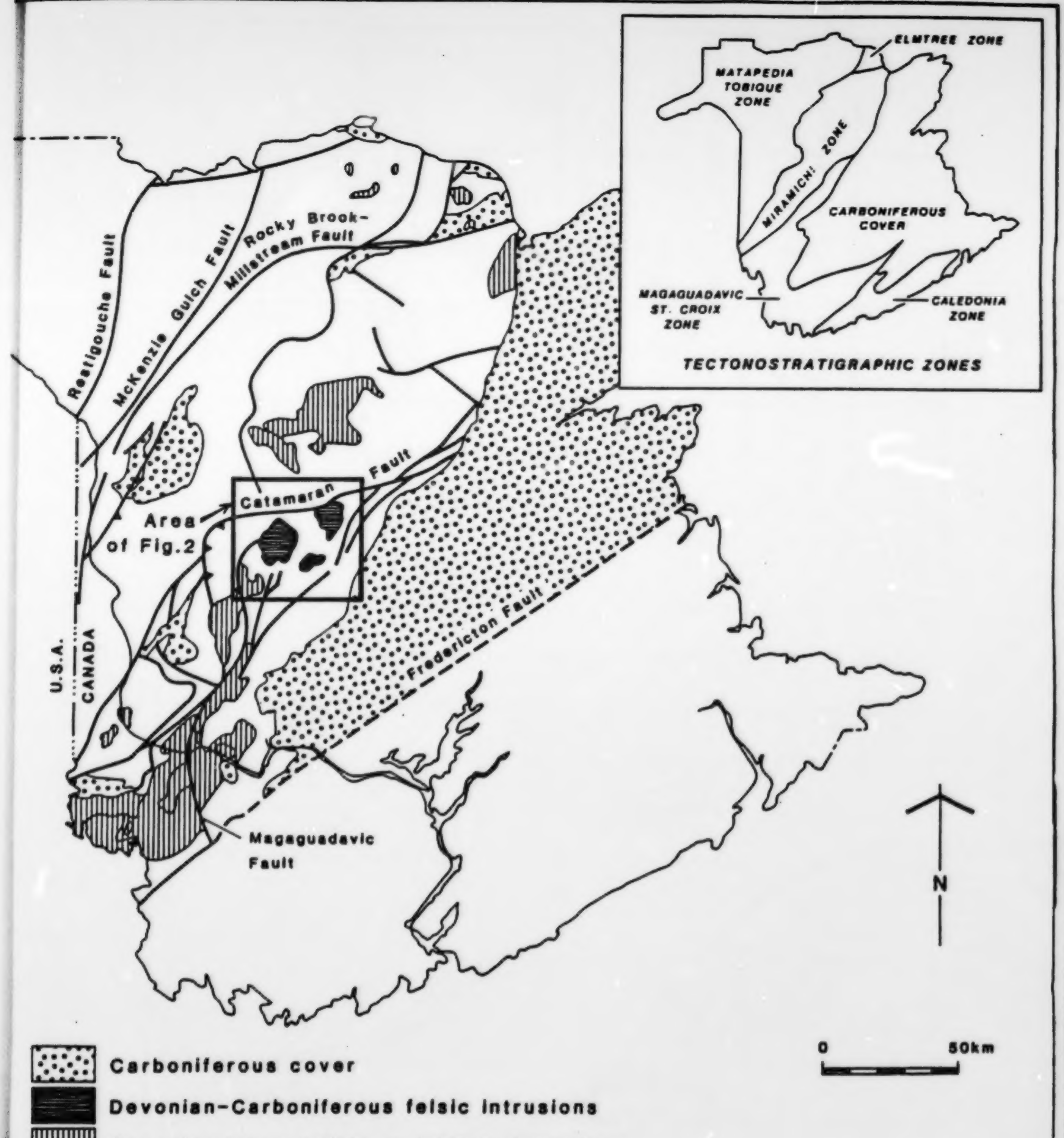

ELMTREE ZONE
MATAPEDIA TOBIQUE ZONE
MIRAMICHI ZONE
CARBONIFEROUS COVER
MAGAGUADAVIC ST. CROIX ZONE
CALEDONIA ZONE
TECTONOSTRATIGRAPHIC ZONES
Restigouche Fault
McKenzie Gulch Fault
Rocky Brook-Millstream Fault
Catamaran Fault
Area of Fig.2
Fredericton Fault
Magaguadavic Fault
U.S.A.
CANADA
N
0
50km
Carboniferous cover
Devonian-Carboniferous felsic intrusions
Devonian intermediate and felsic intrusions

FIGURE 1:

Location of study area: New Brunswick perspective. (LAMOTHE, 1990.)

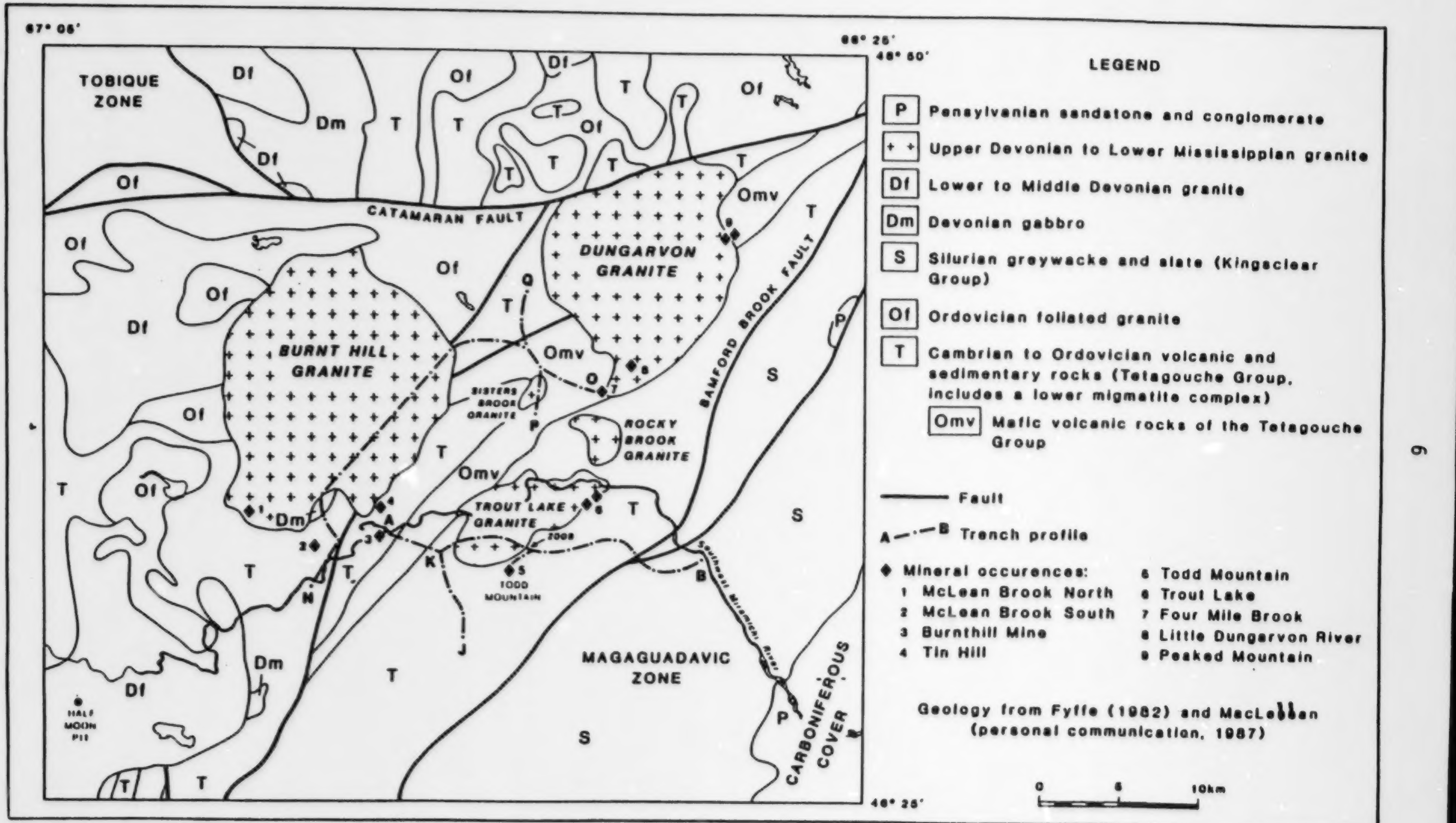

67° 05'
66° 25'
46° 50'
46° 25'
TOBIQUE ZONE
MAGAGUADAVIC ZONE
CATAMARAN FAULT
BAMFORD BROOK FAULT
BURNT HILL GRANITE
DUNGARVON GRANITE
SISTERS BROOK GRANITE
ROCKY BROOK GRANITE
TROUT LAKE GRANITE
TODD MOUNTAIN
HALF MOON PIT
Southwest Miramichi River
CARBONIFEROUS COVER
2008
Df
Dm
Of
T
Omv
S
P
A
B
J
K
N
O
P
Q
T
LEGEND
P Pensylvanian sandstone and conglomerate
+ + Upper Devonian to Lower Mississippian granite
Df Lower to Middle Devonian granite
Dm Devonian gabbro
S Silurian greywacke and slate (Kingsclear Group)
Of Ordovician foliated granite
T Cambrian to Ordovician volcanic and sedimentary rocks (Tetagouche Group, includes a lower migmatite complex)
Omv Mafic volcanic rocks of the Tetagouche Group
Fault
A—·—B Trench profile
◆ Mineral occurences:
1 McLean Brook North
2 McLean Brook South
3 Burnthill Mine
4 Tin Hill
5 Todd Mountain
6 Trout Lake
7 Four Mile Brook
8 Little Dungarvon River
9 Peaked Mountain
Geology from Fyffe (1982) and MacLellan (personal communication, 1987)
0
5
10km

FIGURE 2: Geology of Todd Mountain and surrounding area. (LAMOTHE, 1990).

showing at Todd Mountain is more accurately described as a metamorphosed red manganiferous siltstone (spessartine-rich).

MacLellan et al. (1990) indicate that tin, tungsten, and minor base metal mineralization occurs within a southeast-northwest trending fracture and fault system. The system is believed to have developed within and above the apical portion of the Trout Lake pluton. The mineralizing hydrothermal fluids were likely magmatically derived. The mineralization is both endo- and exogranitic.

MacLellan et al. (1990) describe the Trout Lake granite as a subcircular epizonal, post-orogenic pluton. It is a texturally variable polyphase intrusion dominated by biotite monzogranite. Features of the pluton include: 1) sharp, discordant intrusive contacts; 2) a narrow contact aureole with local zones of intense hydrothermal alteration; 3) isotropic internal fabric; 4) the presence of porphyries; and 5) the development of miarolitic cavities. Geochemically, the pluton is characterized as a mildly peraluminous, high-silica granite. It has been found to contain low concentrations of TiO_2, MgO, CaO, P_2O_5, Sr, ba, and Eu and high concentrations of Y, Nb, Sn, W, Ta, Cs, Th, and U. (MacLellan, 1990).

2.2 GLACIATION

According to Rampton et al. (1984) the Todd Mountain area is covered by late Wisconsinian morainal sediments. Much of the area is overlain by a discontinuous bouldery veneer which is less than 0.5 meters thick. The Trout Lake granite is covered by a isolated bouldery blanket which varies from 0.5 to 3 meters in thickness. Both the blanket and veneer consist primarily of lodgment till, with minor ablation till, silt, sand, gravel, and rubble (Rampton et al., 1984)

There are two meltwater channels in the area. One lies to the north of Todd Mountain, the other is to the east. According to W.W. Gardner (pers. comm., 1990) they both once flowed in an easterly direction. Fluted bedrock, drumlinoid ridges, and glacial straie also indicate an easterly ice flow direction.

2.3 HISTORY OF ECONOMIC INTEREST

2.3.1 Todd Mountain Deposit

Base metal mineralization has been known in the Todd Mountain area since 1939. In 1980, Shell Canada Ltd. identified high tin values in tills. The following year, cassiterite-bearing veins were observed in outcrop near the fire tower site on Todd Mountain. Billiton Canada acquired the property in 1982 and stripped a large area to expose bedrock. In 1983 a line of nine angled hole was drilled across the strike of the veins. Intersections of interest were 0.67% Sn over 1.5 m and 0.18% Sn over 15 m (MacLellan et al., 1990).

The veins of the deposit parallel the regional jointing trend, which in this area is oriented between 115° and 120°, with steep dips to the north. The veins are spaced from 12 to 18 cm apart. Vein mineralization includes quartz, muscovite, beryl, iron-rich biotite (annite), iron-rich chlorite (chamosite), clay minerals, arsenopyrite, cassiterite, and allanite (MacLellan et al., 1990).

2.3.2 Trout Lake Prospect

Eldorado Nuclear staked the first claims in 1979 after stream-sediment anomalies of U were discovered. The company later became interested in anomalous Sn values found in soils. Tin-rich greisen boulders were discovered by Kidd Creek Mines in 1984. They carried out a trenching program in 1985. Cassiterite-bearing greisen lenses from 30 cm to 4 m wide were outlined. They were found to parallel the regional jointing trend (MacLellan et al., 1990).

Five holes were drilled into the two main greisen zones in 1989 by Falconbridge Ltd. Details of the contact relationships were released, however no mention was made of Sn or W mineralization.

Aplite dykes and beryl-bearing pegmatitic pods occur in the granite associated with the greisen zone. Quartz veins containing similar mineralization as those in the Todd Mountain deposit have also been observed. The vein also possess approximately the same trend.

2.4 COTICULES

Coticule is the name given to a rock consisting primarily of spessartine garnet with a sericite or quartzite matrix (Kennan, 1986). The type deposit for this rock is in the Lower Ordivician succession of the southern part of the Stavelot Massif in the Ardennes of Belgium. The coticule there is the sericite-rich variety.

Quartzite coticule horizons are found on the east coast of North America. Similar to the deposits in the Ardennes, they are also found within Ordivician age rocks. The horizons have been correlated across the Atlantic Ocean and are believed to have been formed at the time of the primordial Iapetus Ocean.

Coticule has recently been recognized as a potential guide to base metal deposits. It is believed to possess a strong genetic relationship with the formation of volcanogenic massive sulfide deposits (Kennan, 1986).

Coticule has been identified in the Ordivician age rocks of the Bathurst mining camp in New Brunswick. It was previously erroneously identified in drill core as flow banded rhyolite. This was owing to its extremely fine grained, pink, banded appearance in hand specimen (pers. comm., W.W. Gardiner, 1991).

The Os_1 unit which Todd Mountain lies in is a coticule horizon. The unit is best exposed where it is cut by streams and at topographic highs. This report includes an evaluation of the potential for tracing the coticule horizon using heavy mineral separates from the overlying tills as an exploration tool.

2.5 PREVIOUS WORK

In the early 1960's, Poole and LaChance performed a heavy mineral study in the area. However, they worked with placer pan concentrates and their study of the heavy mineral fraction was by x-ray fluorescence analysis. Their objective was to confirm that tin and tungsten minerals were associated with the Devonian intrusives. While this has subsequently been supported by later more detailed studies, several factors are worth noting from their early investigation.

In the stream sediments they found (Poole and LaChance, 1964) that 1) cassiterite was not readily identified in the field, 2) zirconium distribution roughly parellelled yttrium distribution, 3) radioactivity of untreated concentrates showed a weak correlation with zirconium, yttrium, tin, and tungsten, and 4) in their opinion, manganese was mainly concentrated near the granitic terrains. However observations of their maps show low Mn values immediately overlying the granites. The concentrations are notably elevated at and just below locations where streams cut the Os_1 (Todd Mountain) horizon. This is likely owing to the lack of information concerning the garnetiferous quartzites (coticule) at that time. They speculate in the report that the high Mn values "probably reflect manganese-bearing garnets from metamorphic rocks" (Poole and LaChance, 1964).

Under terms of the 1984-89 Canada-New Brunswick Mineral Development Agreement, regional till geochemical surveys were conducted in the Miracmichi Zone of New Brunswick (refer to block outlined in FIGURE 1). M. Lamothe, then of the Geological Survey of Canada, carried out extensive till sampling over the Hayesville map sheet (NTS 21 J 10) from 1985 to 1988. FIGURE 3 shows the sample coverage by Lamothe (1990a) in the area which this study investigates.

Lamothe's objective was to use detailed geochemistry in the vicinity of known mineral occurrences as a data base to interpret regional surveys, in terms of geochemical response and dispersal. Dispersal studies conducted by Lamothe dealt

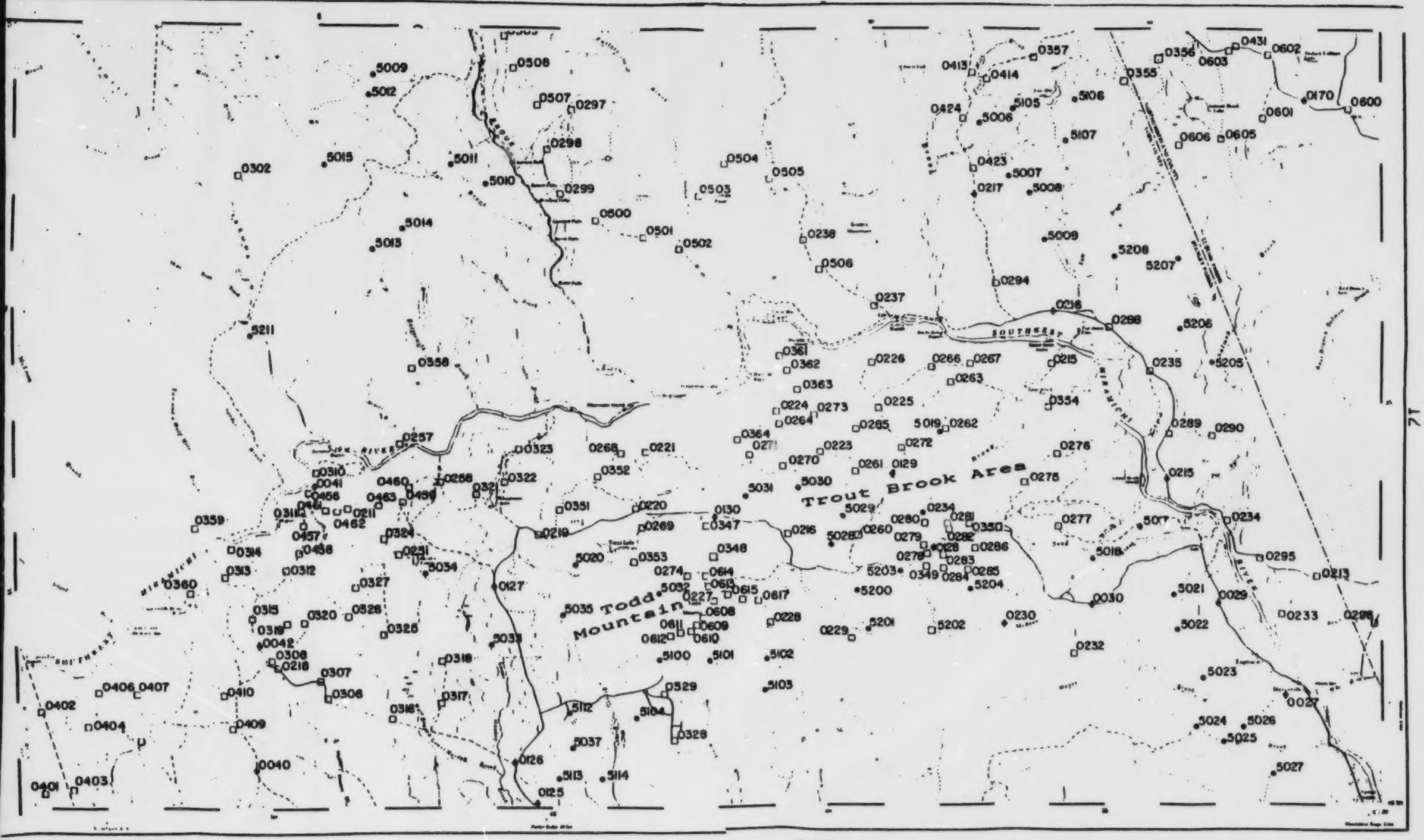

Trout Brook Area
Todd Mountain
HAYESVILLE

FIGURE 3: Sample Coverage and Distribution to the East of Todd

primarily with specific element analyses. Mineralogy was not employed in quantitative results. The length of dispersal trains in the till sheet were determined to be on the order of a few hundred meters (Lamothe, 1990b).

Variations in till Eh and pH may result in elements being released from minerals. These elements may then be dispersed hydromorphically over variable distances, and adsorped or co-precipitated with clays or Fe-Mn-oxides (Rose et al., 1979). A dispersal study based on elemental analyses may incorporate some of these effects. The heavy minerals present in the Todd Mountain area are quite resistant to chemical and physical weathering. The use of stable minerals which can be positively correlated to their ultimate source lithology may provide a better indication of actual physical glacial transport and dispersion. This becomes particularly important in the use of heavy minerals in tills as mapping tools. Hydromorphic dispersion may result in the overestimation of the lateral extent and/or shape of a unit. However, it is noted that in mineral exploration their are instances where a hydromorphic halo may provide a better geochemical target.

3.0 METHODOLOGY

Detailed descriptions of the various methods outlined in this section are given in APPENDIX I. The following section consists of brief statements on each method. In most cases they outline factors which the selection of the particular method were based on and problems which arose in the process.

3.1 SAMPLE REDUCTION

3.1.1 Wet Sieving

The initial wet sieving was performed to remove material which was greater than 1 mm in diameter and the clay fraction. Since the study was intended to be performed primarily by grain mount analysis, the minerals had to be at least of silt size, but preferably no larger than medium grained sand.

3.1.2 Gold Hound (Wheel)

This stage performed the primary bulk separation of the heavy minerals from the lighter fraction. The sample was typically reduce to about 5 to 10 percent of the initial weight. Preliminary trials were run for 30 minutes. However it was noted eventually that in many samples only lighter material was being removed after the first 10 to 15 minutes. The majority of samples were run for variable peroids of time based on close observations of the minerals being separated.

3.1.3 Gravity (Shaker) Table

The objective of this procedure was to remove the bulk of the light material which was contributed by the gold wheel separation. This step was found to be extremely important as the efficiency of the heavy liquid separation was notably increased.

The shaker table separates the sample based on both grain size and density. The coarse lighter material is carried off the table first. Again this method was fairly objective in terms of when the operator would stop the separation process.

The light fraction (the portion carried off the table first) was reseparated for the first six samples tested. It was found that a single stage process was extremely efficient. There was practically no fine grained dense material carried off (ie. caught up) in the coarse less dense material of the initial separation. Hence it was necessary to separate each sample only once by this method.

If samples were run for too long, there was an increased risk that some of the heavy fraction would be carried away, particularly the coarser material. Samples were separated conservatively, since the ensuing heavy liquid separation would readily remove the minor excess of light material that remained.

3.1.4 Heavy Liquid Separation

The material from the shaker table was separated using two different heavy liquids. It was initially separated with bromoform (SG 2.89) and later with tetrabromoethane (SG 3.13).

The heavy fraction of three of the samples initially treated with bromoform was reseparated using tetrabromoethane. The float from the second separation (which represents the density interval 2.89 to 3.13) of each sample was analysed by powder x-ray diffraction (XRD) methods (see Section 3.2). It was decided that the suite of samples should be reseparated using the heavy liquid tetrabromoethane due to the abundance of phyllosilicates which would later complicate the thin section analysis.

3.1.5 Magnetic Separation

The magnetite was of little interest in the study. It was extracted, weighed, and later calculated in terms of parts per million (ppm) per bulk sample.

The magnetite was removed from the samples using a hand held magnetic separator. It consisted of magnet on the end of a retractable plunger encased within a stain steel housing.

3.2 X-RAY DIFFRACTION ANALYSIS (XRD)

Samples tested by this procedure were 1) a blue fluorescent mineral, 2) a yellow-orange fluorescent mineral, and 3) three samples from the heavy liquid separation in the density interval 2.89 to 3.13.

The samples were prepared and analysed at the Geology Department at the University of New Brunswick.

3.3 SCANNING ELECTRON MICROSCOPY (SEM) ANALYSIS

Samples 614-1 and 221-1 were selected for chemical analysis by Scanning Electron Microscopy (SEM) based on their representative mineralogies. The samples were carbon coated at SEM lab at Bailey Hall on the University of New Brunswick campus. The minerals of interest were label with markings on the carbon while being observed under an optical microscope.

The minerals were analysed using the energy dispersive system (EDS) on the SEM. Standards were not used since exact chemical compositions were not required. The elements and their approximate abundances were obtained from energy spectrum plots based on collection intervals of twenty seconds.

3.4 POLISHED EPOXY GRAIN MOUNT ANALYSIS

3.4.1 Transmitted and Reflected Light Microscopy

There is no detailed description of the methodology employed in this analysis in Appendix 1. The analysis and identification of the various minerals was achieved optically using standard techniques associated with this type of microscopy (ie. relief, color, form, habit, birefringence and bireflectance, anisotropism, interference figures, a limited number of textural features (exsolution), twinning, etc.).

A Nikon transmitting light microscope was used that had been previously modified to include reflecting light capabilities. This was a necessity in the analysis, since it would have been unrealistic to study the sample intermittently between two microscope depending on whether an opaque or transparent mineral was being observed.

The preliminary investigation of the mineralogy in the samples resulted in 13 separate mineral groups being distinguished.

3.4.2 Automated Stage Counting Apparatus

Once a preliminary investigation of the mineralogy in the sections was completed, the stage of the microscope was fitted with an incremental mineral grain counter.

The counter consisted of a stage apparatus which held the epoxy grain mount. The stage holder was attached by an electrical wire to a counter consisting of fourteen dials. Each time a single count was registered on the dials the stage holder was advance one increment. Thirteen of the dials could register grain counts, while the last dial acted as a blank in advancing the stage through sparse areas of the slide.

All grain counts were started in the same position on the slide. The slides were placed in the holder such that the numbers inscribed on the back of the slides were at the electrical cord end. The first row counted was always at the extreme right hand side of the slide. Each row counted was separated from the adjacent one by six increments of the stage. This ensured that at least 60% of the slide was studied even for the finest grained samples.

Mineral grains were occasionally abnormally large. The sample was always advanced additional increments when the same grain came under the cross hairs more than once.

Only grains that came fully under the cross hairs were counted. If a blank area between one or more grains came into view, then the stage was advanced until a mineral grain fell beneath the cross hairs. This was to avoid biasing counts towards particular minerals by estimating which was closest to the cross hairs.

3.4.3 Criteria for Counting

The number of grains per slide counted was determined through a statistical analysis of the modal mineral abundances in the incremental counting of six samples.

The samples were selected from locations spanning the entire area. Thirteen mineral groupings were counted based on the preliminary mineralogical investigation. Eight groups consisting of 50 grains counts were made for each slide. A statistical analysis of the eight groups was performed. This was to determine the number of grains per slide which needed to be counted in order to obtain representative modal abundances of the minerals. The discussion of the statistics is given in Section 5.2.

3.5 DATA REDUCTION AND PLOTTING

Data reduction was performed using a spreadsheet. The line, scatter and contour plots were computer generated. The statistical analyses were performed on STATGRAPHICS ver 4.0.

4.0 DATA

4.1 SAMPLE LOCATIONS

One hundred and twenty three samples from the Todd Mountain area were initially selected for analysis. However approximately one half of the specimens did not possess an adequate quantity of heavy minerals to allow for preparation of polished epoxy grain mounts.

The sample coverage was previously shown in FIGURE 3. The area was gridded off and the coordinates of each samples were measured. These values were then used to plot the sample numbers and locations of the 63 specimens using a contouring software package. The final result is shown in FIGURE 4.

4.2 SAMPLE WEIGHTS (AND MAGNETITE)

The bulk initial sample weight (before wet seiving), the weight of heavy mineral fraction (SG > 3.1) minus magnetite, and the weight of magnetite are given in APPENDIX II.

4.3 MODAL MINERAL ABUNDANCES

The raw data mineral counts are given in APPENDIX III. These are the actual numbers of each mineral counted. The lower half of each page contains the calculated percentages of each mineral in the mounts.

A summary of the percentages of each mineral or mineral group for the suite of samples is also given in APPENDIX III. Also included are the calculated percentages of total opaque minerals, transparent minerals, zircon and garnet.

1	316	11	5104-C	21	347	31	5029-C	41	280-1	51	235-1	61	233-1
2	5034-C	12	269-1	22	614-1	32	5028-C	42	262-1	52	5206-C	62	213-1
3	321-1	13	268-1	23	5101-C	33	5201+	43	285	53	5205-C	63	296
4	5033-C	14	2211-1	24	615	34	5200-C	44	275	54	234-1		
5	322-1	15	5032-C	25	5031-1	35	260-1	45	R215	55	5021-C		
6	219-1	16	5100-C	26	264	36	261	46	276-1	56	5022-C		
7	5035-C	17	329-1	27	270-1	37	225	47	277-1	57	5023-C		
8	5112-C	18	R328	28	5102-C	38	272-1	48	R232	58	5024-C		
9	5113-C	19	610-1	29	5103-C	39	5203-C	49	5018-C	59	5025-C		
10	5114-C	20	274-1	30	273-1	40	5202-C	50	288-1	60	5027-C		

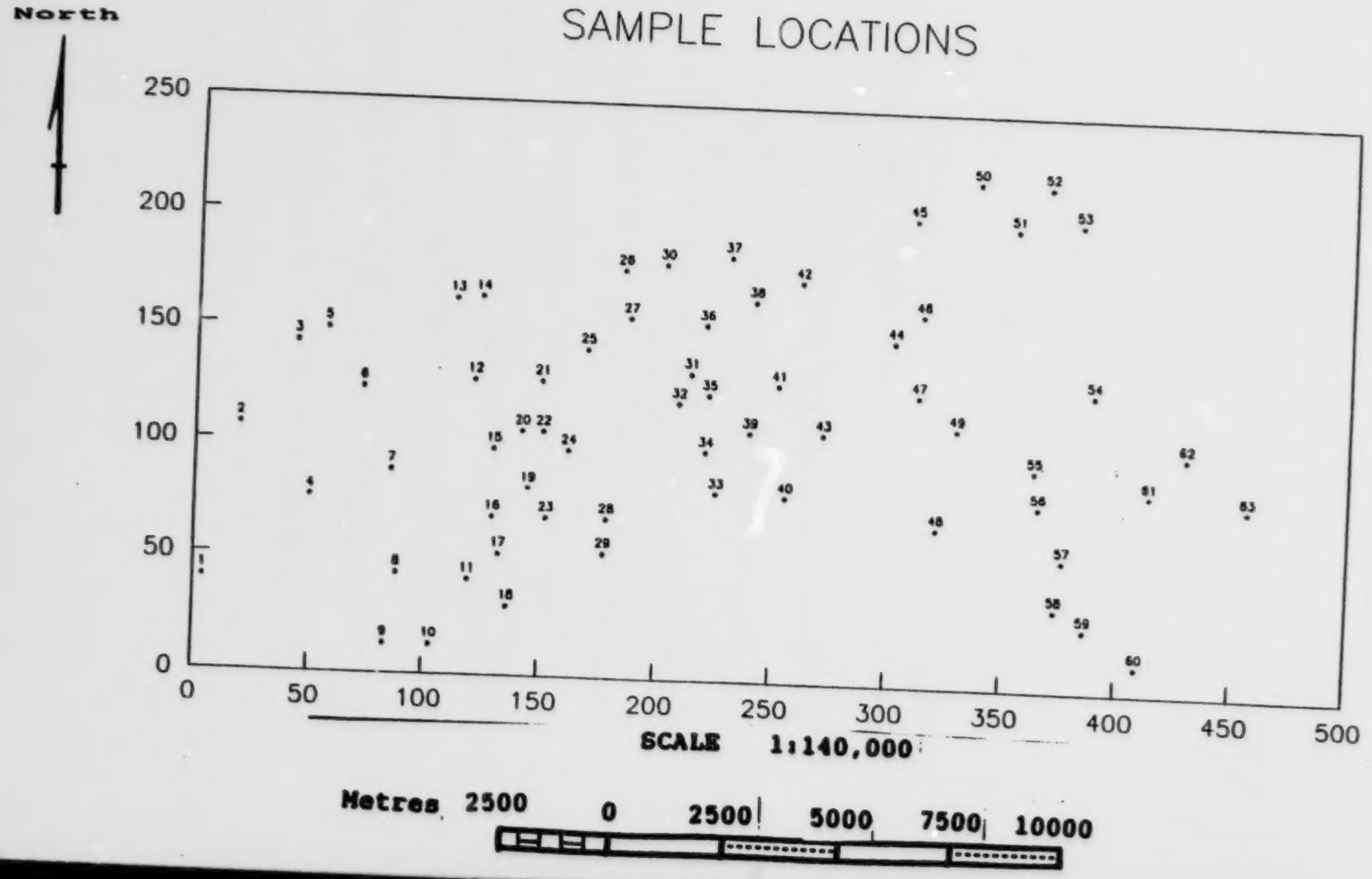

SAMPLE LOCATIONS
North
250
200
150
100
50
0
0
50
100
150
200
250
300
350
400
450
500
SCALE 1:140,000
Metres 2500
0
2500
5000
7500
10000

FIGURE 4

4.4 SCANNING ELECTRON MICROSCOPE (SEM) ENERGY DISPERSIVE SYSTEM (EDS) ANALYSIS

The energy spectrum plots with the element labels on their respective energy peaks is given in APPENDIX IV. A brief descriptive title is given in the lower left hand corner of each plot.

The first ten plots are analyses of the transparent red brown phase that was common throughout the samples. Plots 11, 12, and 13 are of V-Ti-Mn-Fe inclusions which are found in many of the minerals in the area. Finally, plots 14 through 20 are analysis of zircons.

4.5 X-RAY DIFFRACTION (XRD)

The XRD patterns and μPDSM reports for the samples analysed are given in APPENDIX V. The μPDSM reports give the input pattern (d-spacings), the identified phases, and a summary of the d-space and intensity comparisons.

Patterns one and two, are respectively, the yellow-orange and white-blue fluorescent minerals. The third and fourth patterns are the analysis of the float from the secondary separation of the bromoform heavies with tetrabromoethane. The third and fourth patterns (samples 316-1 and 613-1) are almost identical when overlain. Hence only one μPDSM search was performed.

4.6 INCREMENTAL COUNTS FOR STATISTICAL ANALYSIS

APPENDIX VI contains the raw data for the eight groups of fifty counts which were performed on for preliminary samples (260-1, 276-1, 5022-C, 5100-C). This data was employed in a statistical analysis to determine the number of grains which needed to be counted in order to obtain an accurate representation of the modal mineral abundances in the samples.

5.0 ANALYSIS AND RESULTS

5.1 GRAIN MOUNT MINERALOGY

The particulars of the more important mineralogies observed in the grain mounts is discussed in this section. At least twenty five optically distinguishable phases were present in the sections. The ones which were deemed significant to the study are discussed below.

5.1.1 Geothite

This mineral caused some difficulties in the early stages of the thin section work. It often appeared as red transparent grains exhibiting internal layering which closely resembled the zoning found in the cassiterites of the area. In addition, the grains often had quite regular crystal edges and internal features which resembled twinning.

Approximately thirty grains were studied using the energy dispersive system (EDS) on the scanning electron microscope (SEM). A criterion was determined for the identification of geothite based on the correlation of the measured chemistries and the observed textures and forms of the grains.

The EDS plots are shown in PLOTS IV.1 through IV.10. PLATES VII.1 and VII.2 show photos graphs of the geothite in both reflected and transmitted light. The EDS scans (APPENDIX IV) show the majority of the grains to contain only iron with minor amounts of silicon and aluminum. The later are likely present as minute inclusions in the secondary mineral. PLATE VII.3 shows goethite surrounding a core of sulphide. This occurred in only approximate 1 or 2% of the goethite grains observed. More often the goethite was present as deep red colloform masses (See PLATE VII.4) with either a regular or irregular habit. The "zoned crystals" are believed to result from pyrite replacement.

5.1.2 Coticules and Whole Garnets

The garnets in the area are of the spessartine variety with a lesser to equal component of the almandine endmember occasionally present. PLATE VII.5 shows a typical garniferous section in transmitted light.

The whole garnets often had dark inclusions of what appears in relflected light to be sulfides, gold, electrum or possibly pyrolusite. PLATE VII.6 shows a typical garnet with opaque inclusions in transmitted light. The association with gold (or electrum) was positively confirmed in several grains where the inclusions were sufficiently large to allow positive identification. Inclusions of grey opaques were also observed. Typical EDS scans are shown in PLOTS IV.11 to IV.13. The grey inclusions consisted of varying amounts of vanadium, titanium, manganese and iron. Similar inclusions were also identified in sillimanite and pyroxenes.

Coticules represent fragments of the Todd Mountain unit. They consist of spessartine garnets in a quartzite matrix and less commonly one of chlorite. PLATES VII.7 and VII.8 show a typical coticule in transmitted light under plane polarized light and with the upper polarizer inserted. Under cross polars the small dark spheres go to extinction while the matrix shows the characteristic colors of quartz or quartzite. PLATE VII.9 shows a coticule with a chloritic matrix. In transmitted light the interstitial material between the garnets appear as a very distinctive green color.

5.1.3 Zircons

Two types of zircons were distinguished in the area. PLATE VII.10 shows both the zoned and the clear fractured types. Other examples of the zoned zircons are given in PLATES VII.11 and VII.12. The zoned zircons possessed very distinctive and well defined crystal habits. Both types of zircons were readily identified in transmitted light due to their extreme birefringence (and hence bright display of interference colors).

Before the heavy mineral fractions were prepared as polished epoxy grain mounts, they were observed in their loose grain form under ultraviolet light. An intense yellow-orange fluorescent phase was observed. Approximately twenty of the larger grains were extracted from the sample and prepared as powder mounts on a glass thin section. The slide was analyzed by x-ray diffraction techniques and the phase was identified as being zircon. APPENDIX V provides the data and analysis from the x-ray diffraction investigation.

Attempts were made to account for the fluorescent nature of the zircons. Observations under the microscope showed that not all zircons were fluorescent. The zoned zircons were found to be rarely fluorescent. PLOT IV.14 through IV.20 shows typical analyses from EDS scans of the zircons. Approximately 15 analysis of zircons were performed under the SEM. The scans did not indicate the presence of any trace elements. It was suspected that uranium or rare earth elements may have been the cause of the fluorescent nature of the grains, especially since the Trout Lake granite is known to be enriched in both these elements. It is still possible that these elements may be responsible, since their concentrations may well be below the detected limits of the EDS scan. One final possibility exists to explain the fluorescent nature of the grain. Water within the crystal structure of minerals has been known to cause this phenomenon. The EDS scan would not have detected water since it is sensitive only to minerals above sodium in the periodic table of elements.

5.1.4 Sillimanite

PLATE VII.14 shows a grain of the fibrolite form of this mineral. Sillimanite was readily identified in reflected light due to this distinctive texture and its high birefringence.

The fibrolite masses often contained large dark inclusions of the V-Ti-Mn-Fe oxides. These have been previously mentioned in the section on garnets.

5.1.5 Cassiterite

Cassiterite was found to be quite abundant in weathered soil samples taken directly from the outcrop surface. However, the till samples showed very minor quantities of this mineral. The low percentages did not permit this mineral to be counted as a distinct group.

When the mineral was observed it was found as quite small fragments. The brittle nature of this mineral may prevent it from useful in the study of tills. The cassiterite fragments were often difficult to distinguish due a lack of visible zoning and twinning in the crystals. If it is necessary to incorporate this mineral in later studies, then it is suggested that tin etching techniques be employed. However, it is noted that the use of acids may be detrimental to the surface of the polished thin sections.

PLATE VII.14 shows a typical whole cassiterite grain from the heavy mineral fraction of the sediment taken from the surface of the weathered outcrop.

5.1.6 Ilmenite

PLATE VII.15 shows a typical grain of ilmenite as observed in the sections. This mineral was easily identified based on its distinctive textures from the exsolution of hematite and magnetite.

5.1.7 Native Gold and Electrum

Minerals grains which appear to be gold or electrum were observed in fourteen slides. The identification was based on color, extreme sectility, lack of anisotropism in reflected light, and the absence of alteration rinds.

Two distinct groups of grains where identified based on texture and color. The first appears to be native gold. The grains for this group are texturally uniform and smooth surfaced. Their color is a deep yellow orange. An example is shown in PLATE VII.16. Note the needle scratch across the center of the grain.

The second grain type is believed to be electrum. It is texturally similar to native copper. The grains are often elongate and irregular. The color is yellow but with a whitish-pink tinge. The later coloring is thought to be due to the mixture of gold with native silver and/or color. A wide range of variations in the color are present. PLATE VII.17 and VII.18 are examples of electrum as observed in the polished thin sections. High magnification of the grains showed that the electrum may contain minute inclusions of silicates or oxides.

This mineral should be investigated further preferably on the SEM employing an EDS analysis similar to that performed on the other minerals.

5.1.8 Other

Several additional phases were investigated in this study however they proved to be of little importance in the area. They are mentioned here for the sake of completeness.

Tourmaline was observed in variable and very minor quanitities throughout the sample suite. Initially there was some confusion with the abundant amphiboles which often displayed parallel extinction similar to the tourmaline. Interference color could not be used as a distinguishing feature since the slide were often thicker than 30 μm and thus the amphibole also exhibited extreme colors under cross polars. The eventual criterion employed was the length fast nature of the tourmaline crystals (whereas the amphiboles are generally length slow).

As previously mentioned the amphiboles were quite abundant in the sections. They were counted as a separate group, however they were ultimately found to provided very little useful information on the area.

In addition to pyrite, several other sulfides were observed in the samples, however, they were present in minor quantities which did not justify individual counting groups.

Pyrrhotite was found in both the magnetically separated fraction and the normal thin sections. This indicates that both the ferromagnetic (monoclinic pyrrhotite) and non-magnetic (hexagonal pyrrhotite) may be present. This would be consistent with the potential temperatures of formation for vein occurrences. A beta-transistion occurs for pyrrhotite at 320°C. This transistion is independent of composition and manifests itself as a discontinuity in magnetic susceptibility (Craig and Scott, 1976). It is possible that vein minerals in the northwest-southeast trending fractures of the area crystallized out of solution at temperatures bracketing the Neel point of pyrrhotite.

Several grains of the copper iron sulfide, bornite (Cu_5FeS_4), were observed. They generally exhibit extensive covellite (CuS) alteration (See PLATE VII.19).

5.2 STATISTICAL ANALYSIS TO DETERMINING COUNTING CRITERION

APPENDIX VI gives the data from the four samples on which eight consecutive groups of 50 counts were made. The tables in the appendix also give the recombination of the 50 count groups into collections of 100 and 200 grains with all three sets of data being recast on a 100 count basis. The mean, standard deviation, maximum and minimum values have been determined for each mineral group. As would be expected the means remain the same however their is a significant decrease in the standard deviation as the groupings become larger. This provides support for the idea that the greater the number of grains counted the better the representation of the modal mineral abundances obtained.

The tables also show the calculated cumulative percentages for each of the mineral groupings. FIGURES 5 through 8 are plots of this data for selected mineral groups. These graphs show that for counts from 50 to 200 the cumulative percentages tend to be very erratic. At about 200 to 250 counts the percentages level out and begin to resemble the those of the higher cumulative counts. A counting criteria of 250 grains was selected for this suite of samples based on the fact that a greater number of counts provides a better representation of modal abundance. The later fact was previously established through observations of decreasing standard deviations with increased group sizes.

5.3 CONTOUR PLOTS

Contour plots of the minerals are given in APPENDIX VIII. Many of the mineral groups that were prepared as contour plots do not exhibit any meaningful relationships with respect to provenance, topography, or dispersal in the area. These plots are also included in APPENDIX VIII for the sake of completeness. They do not contribute any useful information to the study other than the fact they should not be used again in similar studies of the area.

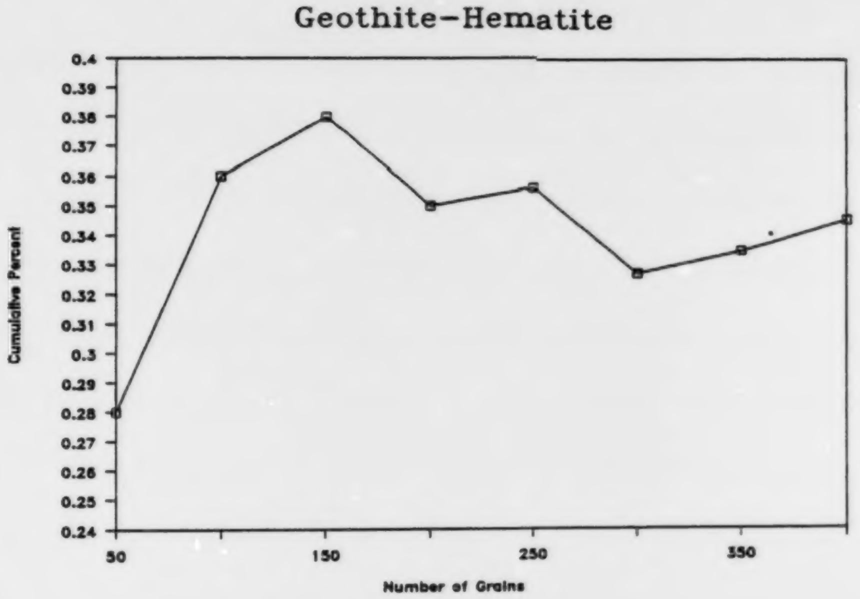


FIGURE 5: Plot of cumulative grain counts: Goethite-Hematite

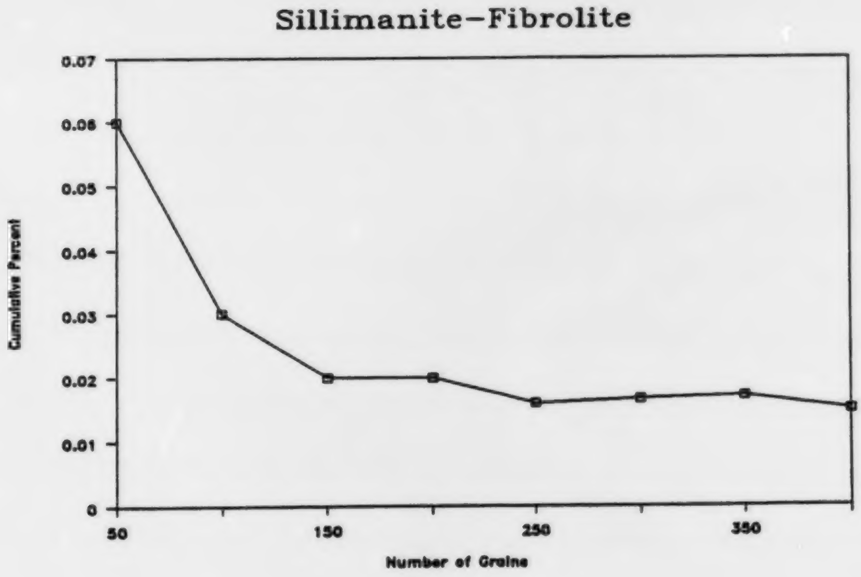


FIGURE 6: Plot of cumulative grain counts: Sillimanite-Fibrolite

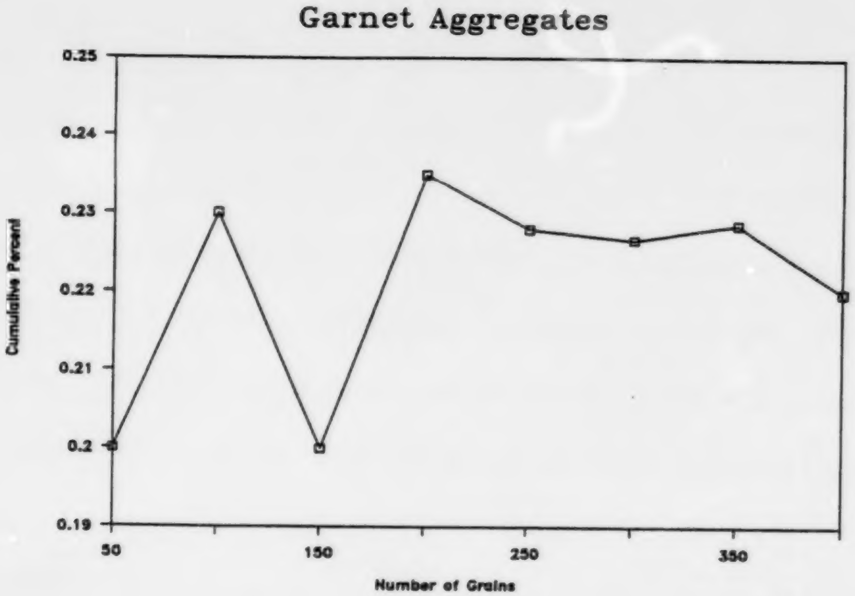


FIGURE 7: Plot of cumulative grain counts: Coticule

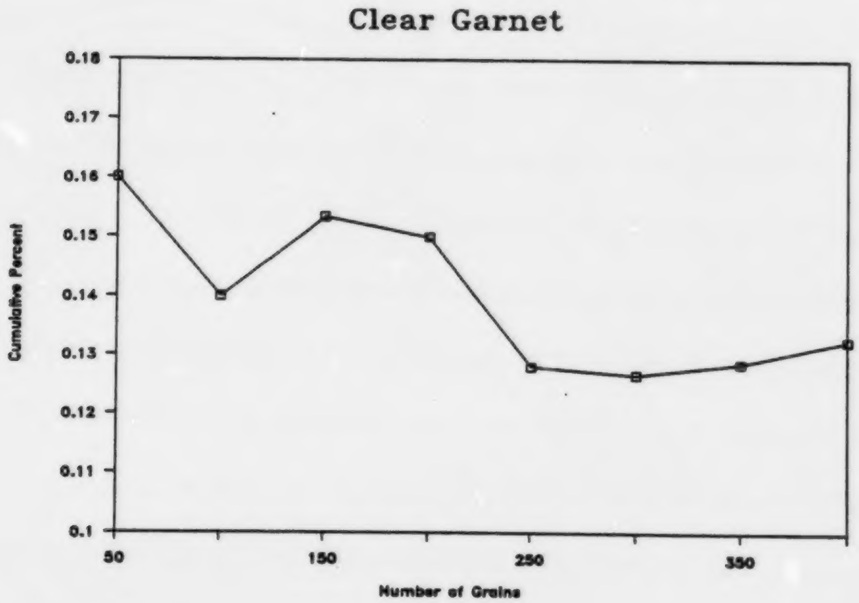


FIGURE 8: Plot of cumulative grain counts: Clear Garnet

6.0 DISCUSSION

6.1 PROVENANCE

Zircon and garnet were found to show a strong correlation to their known source units. Each of this minerals were subdivided during the counting process. Zircons were identified as being zoned and clear. Garnets were separated into groups of whole garnet and coticules (garnet aggregates). The contoured data are shown in PLOTS VIII.21 through VIII.26 (APPENDIX VIII).

The major concentrations of zircon are found in tills overlying the Trout Lake pluton. The zircons do not exhibit any relationship with the Todd Mountain horizon. There is a somewhat erratic distribution of low zircon values throughout the area. This is likely due to the presence of several other large granitic bodies in addition to the Trout Lake pluton. The area would be expected to have higher than normal concentrations of zircon in the sediments.

The individual garnets and the coticule fragments show a good correlation with the Todd Mountain horizon. The garnet enriched samples plot almost exclusively along the length of the northeast-southwest trending metasedimentary horizon. (See PLOTS VIII.24 and VIII.26)

Goethite was a third mineral which exhibited some form of correlation to a source area. The contoured data for this secondary mineral is shown in PLOT VIII.27. The distribution strongly parallels the Todd Mountain horizon. As previously mentioned the goethite is believed to have formed from the oxidation and reprecipation of iron from mobilizing groundwaters. It appears that sulfide minerals in the metasedimentary horizon have provided iron to the ground and surface waters. The iron-rich water seems to have migrated down the southeast flank of the topographic high and precipitated its load of iron along the base of the hill. This has likely occurred due the greater abundance of organic matter and hence reducing conditions in the low region.

There was a good correlation between the gold occurrences and the metasedimentary horizon. The gold values have been plotted as occurrences rather than contoured data since observations of this phase in the thin sections was generally limited to one or two grains per slide (See PLOT VIII.28). The distribution roughly parallels the Todd Mountain horizon with the majority of occurrences being found along and to the southeast of the unit. Several of the data points plot to the northwest of the horizon. While the data points tend to parallel the metasedimentary unit, it should be noted that the mineralization is most likely associated with the northwest-southeast trending set of fractures which crosscut the area. The gold probably has a vein origin similar to that of the tin, tungsten, and base metals.

The minerals tourmaline, ilmenite, amphibole, sillimanite, and epidote did not show a distinct correlation to any of the underlying rock units.

6.2 TOPOGRAPHY

The Todd Mountain horizon represents the major topographic anomaly in the area. It is an extremely competent unit since it is comprised of garnet in a quartzite matrix. The only other significant geomorphological feature in the area is the southwest Miramichi river channel.

The topographic high along the metasedimentary unit drastically decreases in the southwest corner of the area. PLOTS VIII.21 to VIII.26 which are the contoured zircon and garnet mineral data show very flat regularly spaced values in this region. In general, the lows in the mineral data are observed to coincide with the topographically flat areas.

The highest values are in locations where the glacier would have passed over the ridges and scrapped material from the protruding rock. Poor correlations, attributed to glacial mixing (c.f. Broster, 1986), provides evidence of glacial mixing as the ice passed across the high areas.

To further evaluate the mixing hypothesis the area was split into three regions: the area to the northwest of the Todd Mountain horizon (Block 1), along the horizon (Block 2), and to the southeast of the unit (Block 3). The data were compared for the zoned and clear zircons, and the coticule and whole garnets. The results are shown in FIGURES 9 through 14.

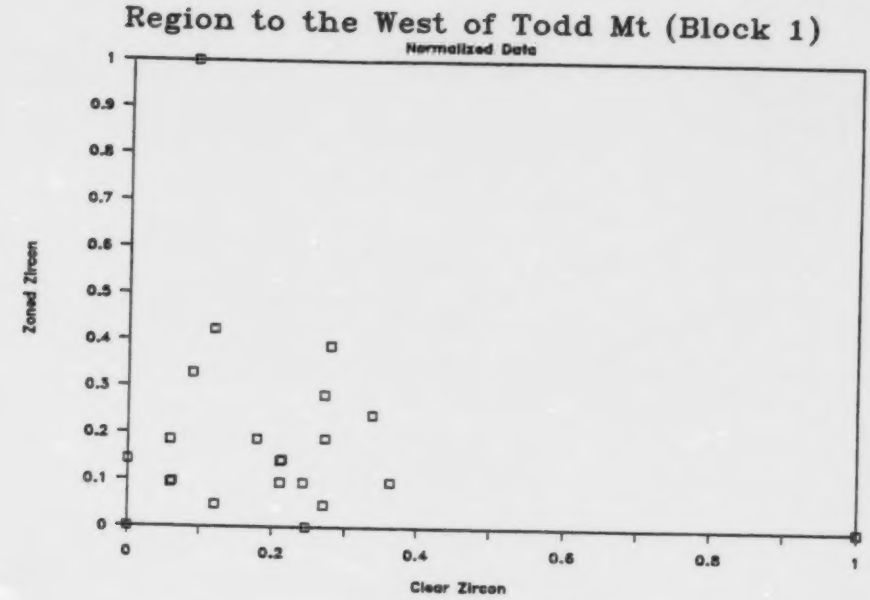


FIGURE 9: Mixing analysis: Zircon (Block 1)

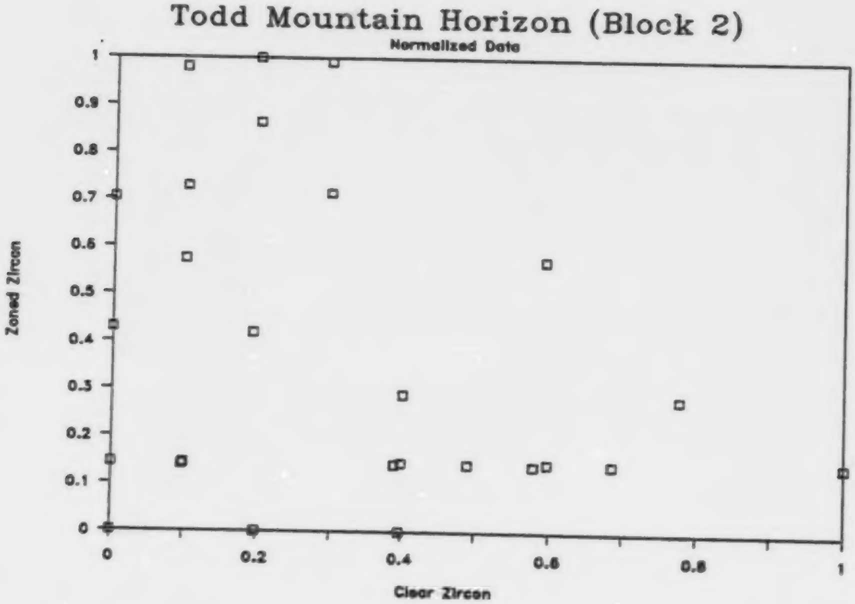


FIGURE 10: Mixing analysis: Zircon (Block 2)

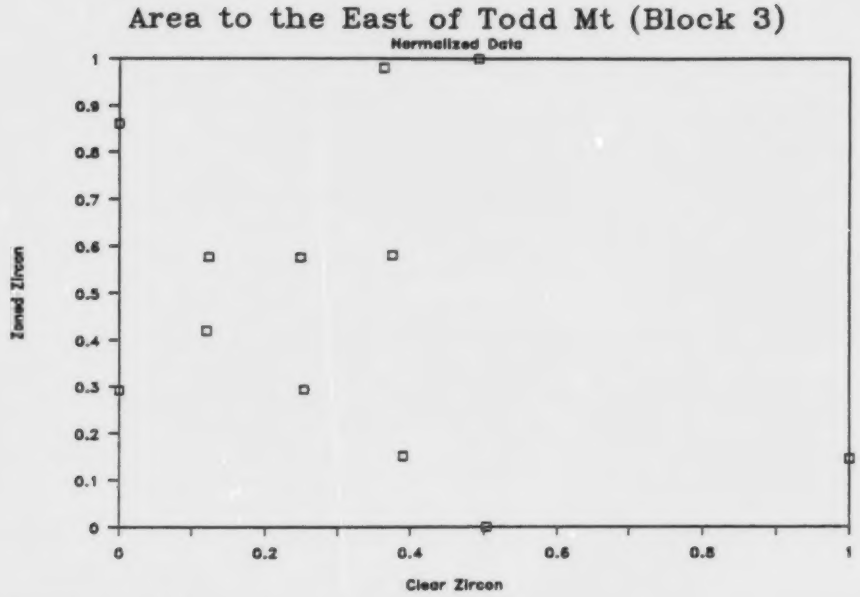


FIGURE 11: Mixing analysis: Zircon (Block 3)

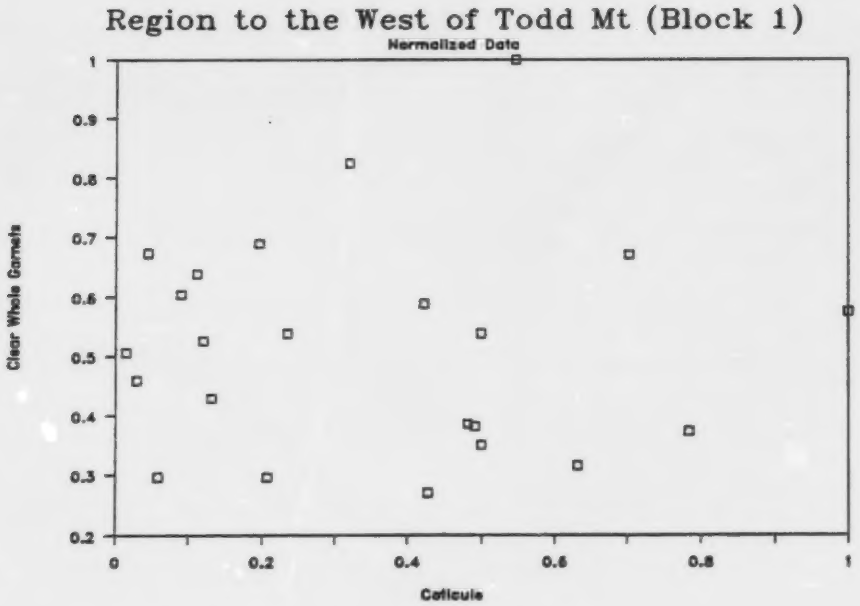
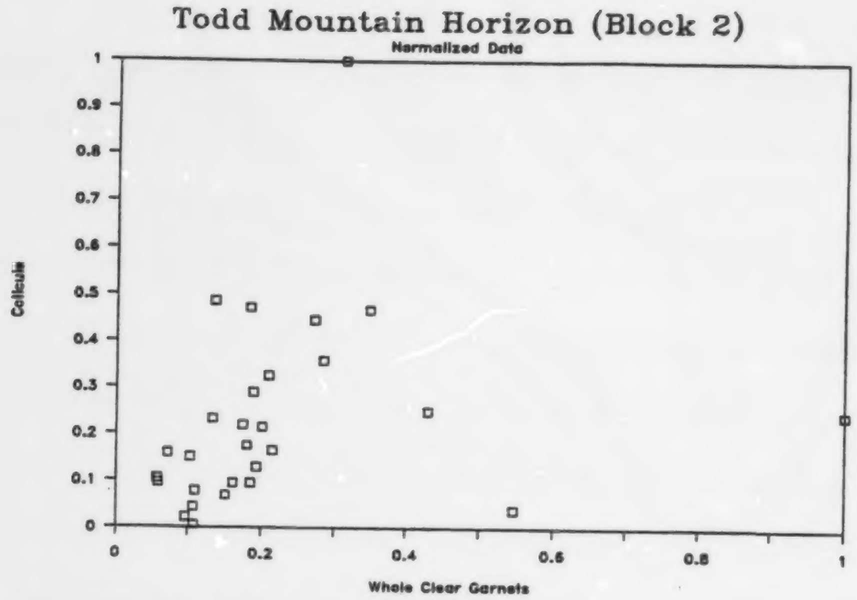
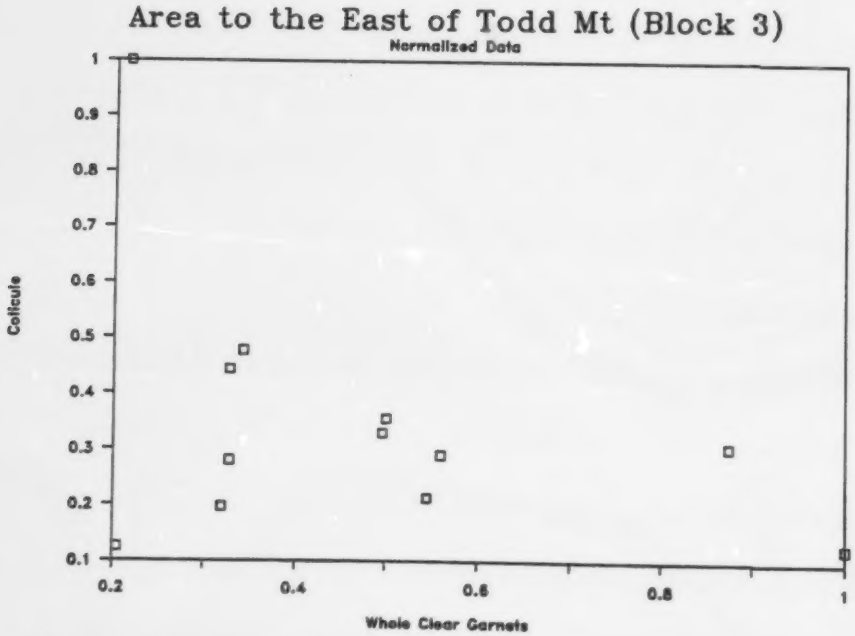


FIGURE 12: Mixing analysis: Garnet (Block 1)



Todd Mountain Horizon (Block 2)

FIGURE 13: Mixing analysis: Garnet (Block 2)



Area to the East of Todd Mt (Block 3)

FIGURE 14: Mixing analysis: Garnet (Block 3)

The zircon data is scattered for the samples in Blocks 2 and 3. The best correlation is found for the zircons in Block 1 to the northwest of Todd Mountain. This supports the mixing hypothesis in that the zircon source is the Trout Lake granite to the northwest of the ridge. The correlations may become poor because the granite derived material was glacially transported up over the ridge and mixed with ablation till higher up in the ice.

The correlations for the coticules and garnet are found to be poor for Blocks 1 and 3. The best correlation is found along the metasedimentary source horizon. Again, this is to be expected, since the till overlying its source should contain the best representation of the underlying mineralogy. The till up-ice from the ridge should show erratic garnet values since its lacks a distinct source. The till down-ice of the ridge may be showing poor correlations due to mixing over the topographic high.

6.3 DISPERSION

Dispersal in the area appears to be traceable for distances on the order of several hundred meters to a maximum of about three kilometers. The garnet dispersal plume at Todd Mountain (PLOTS VIII.24 to VIII.26) which tails to the east is based on seven to nine data points. It is directed due east and provides the best indication of glacial dispersal in the area. Other garnet dispersal plumes along the ridge similarly headed to the east. They appear to be traceable for shorter distance. There is clearly a relationship between the geomorphology of the source unit (particularly elevation) and the length of the dispersal plume.

The garnet crystals generally did not appear to be extensively eroded or broken. Often the outer crystal faces where still intact showing only minor amounts polishing. The lack of degradation in this mineral lends further support to the interpretation of short glacial transport.

The zircons contours over the Trout Lake granite support the correlation between topography and dispersal. While the zircon values overlying the pluton are high, the length of the dispersal plume is limited in comparison to the more elevated metasedimentary ridge.

The short dispersal fans are such that the heavy mineral fraction in the till may prove to be a better mapping tool than an exploration target. If the heavy minerals are to be used as an exploration target the survey would have to be carried out on tight closely spaced grids. Sampling should be done on approximately 100 to 250 meter centers.

Contour highs for goethite parallel the Todd Mountain horizon. As previously mentioned this is likely due to hydromorphic dispersion. This is further supported by a lack of plumes directed to the east for the high concentration areas. Goethite should not be used as a mapping tool for the region. Although this mineral may be found useful through analysis of core to rim ratios for the sulfide-rich grains. This may be employed as a secondary method for mapping the Todd Mountain horizon should problems arising in using the garnets as tracers.

6.4 CORRELATION OF MINERALOGY

It was uncertain in the early stages of the project whether or not the coticules and whole garnets were both originating from the Todd Mountain horizon. Observations of thin sections from the unit showed abundant sources for coticule fragments, However, few whole garnets were observed in the rock sections and certainly none were observed to be 1 mm in diameter which was fairly common in the grain mounts.

The correlation between coticules and the whole garnets is shown in FIGURE 15. Extreme points are interpreted to represent extensive glacial mixing and thus are likely to confuse mineral correlations. When a few of the more extreme points were removed from the data, the calculation of a correlation coefficient yielded a value of approximately 0.75.

EDS analysis on the SEM has also shown that the coticule and whole garnets are composed primarily of the spessartine (Mn) endmember with lesser amounts of the almandine (Fe) component.

Observations in both transmitted and reflected light showed a further number of similarities. The whole garnets and the garnets within the coticule fragment both contained abundant inclusions of oxides, sulfide, and possibly gold or electrum. As well fluid inclusions containing vapor, liquid, and occasionally daughter minerals were present. The color of the grains was also consistently the same.

The strong correlation, similarity of chemistry, and properties observed beneath the microscope indicate that the individual whole garnets are most likely

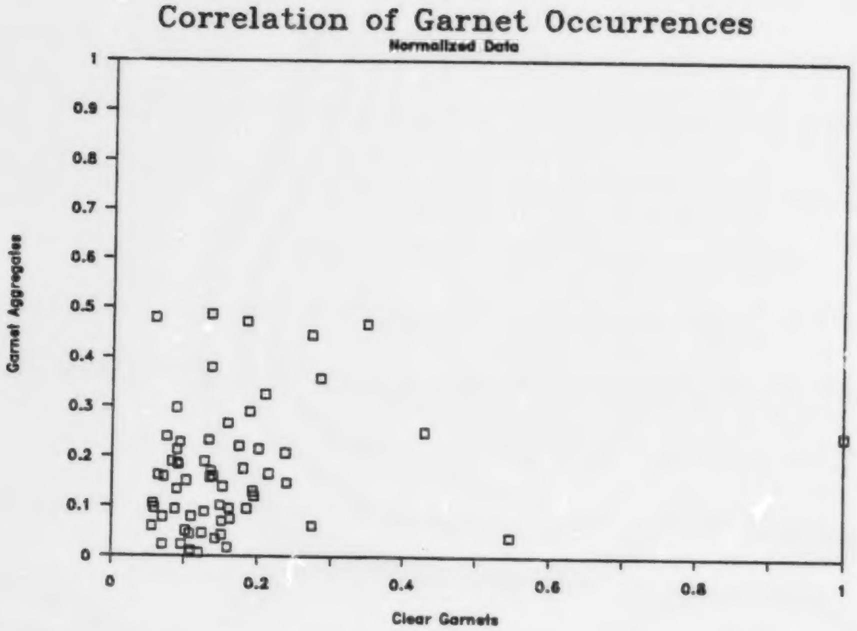


FIGURE 15: Scatter Plot: Coticule vs. Whole Garnet

from the coticule horizon. The larger grains were probably not seen in the rock sections from Todd Mountain since a slide represents a very small fraction of the whole unit. The tills have accumulated from considerable exposures of the unit and thus have a much greater probability of acquiring the rarer large crystals.

An interesting and important correlation observed in the grain mounts was the presence of large inclusion of gold or electrum on the edges of garnet grains. This further supports the idea of mineralization being associated with the Todd Mountain horizon.

The correlation coefficient is quite low for the zoned and clear zircon data for the entire area. The value is considerably higher when the data are separated into the three blocks (areas) as previously discussed. Furthermore, when the two sets of data are contoured individually and collectively, both show strong relationships with the Trout Lake pluton viscinity (PLOTS VIII.21 and VIII.22). Based on this information it is believed that both types of zircon are indicative of the Trout Lake unit.

6.5 CORRELATION WITH LAMOTHE (1990) GEOCHEMISTRY

Since the samples used in this project were the remaining splits from the investigation by Lamothe (1990), the measured mineral data was analyzed for correlations with the geochemistry from the earlier study.

Lamothe's (1990) report presents the data from his elemental analysis with interpretations indicated as forthcoming. The results for Fe, Mn, Cu, Pb, Zn, Cr, Co, Sn, W, Au, Ag, U and Th were extracted for the samples used in this study. Correlation coefficients were calculated for these elements against total garnet, total zircon, and goethite. The best correlations were prepared as scatter plots and are shown in FIGURES 16 through 26.

Garnet shows good correlations with most of the base metals. This is interpreted as indicating an association for the metasedimentary horizon and the mineralized crosscutting vein work.

Zircon shows a weak correlation with uranium and thorium. This is not interpreted as an indication these elements are present in zircon (and possibly responsible for their fluorescent nature). Instead it is believed that the correlation arises out of a similarity of origin. The Trout Lake pluton is known for it's high uranium and thorium content and it has already been shown that the zircon concentrations in the area are likely derived from the granite.

Goethite and iron correlations were found to be very poor. This is probably due to the ubiquitous nature of iron. Also, the size fractions analysed by Lamothe were very fine grained (2 μm and < 63 μm). The goethite observed in the polished grain mounts was consistently of size 0.1 to >1 mm.

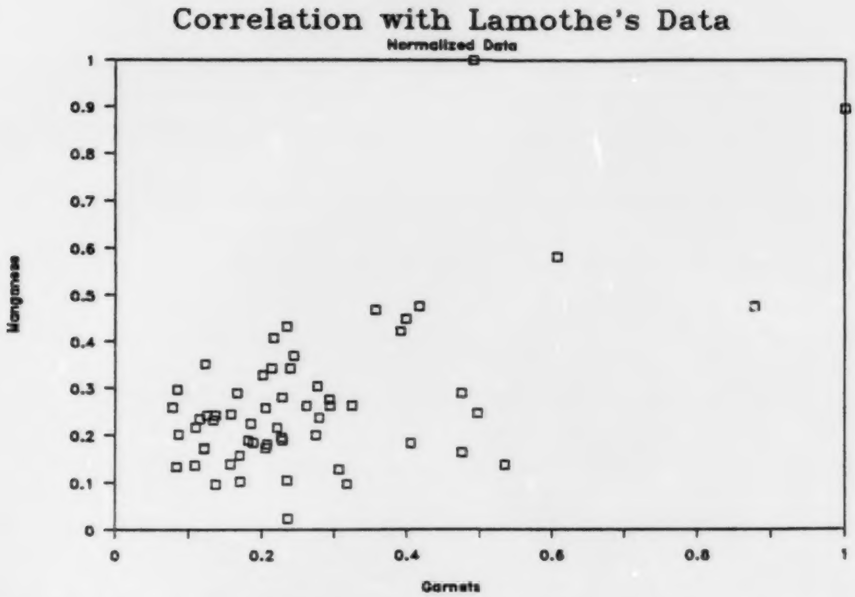


FIGURE 16: Correlation with Lamothe's (1990) data: Garnet vs. Mn

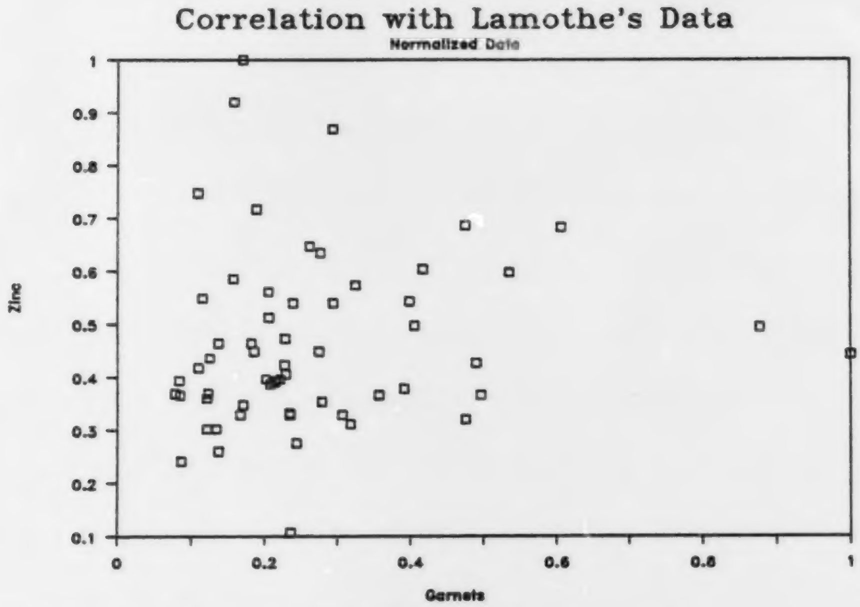


FIGURE 17: Correlation with Lamothe's (1990) data: Garnet vs. Zn

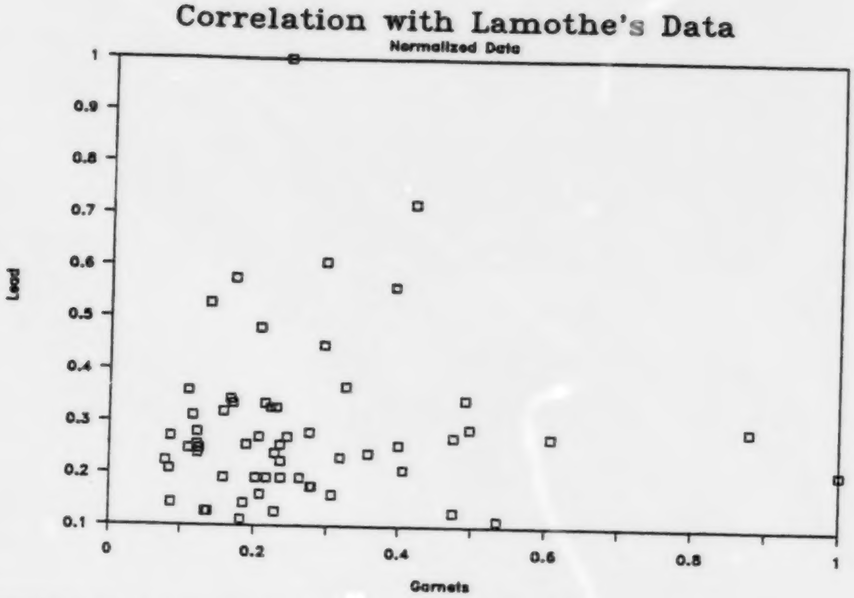


FIGURE 18: Correlation with Lamothe's (1990) data: Garnet vs. Pb

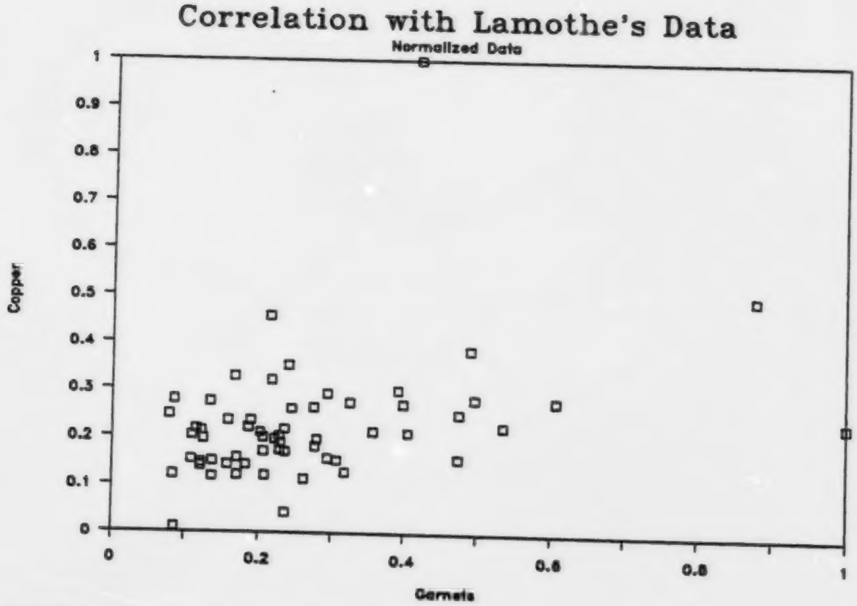


FIGURE 19: Correlation with Lamothe's (1990) data: Garnet vs. Cu

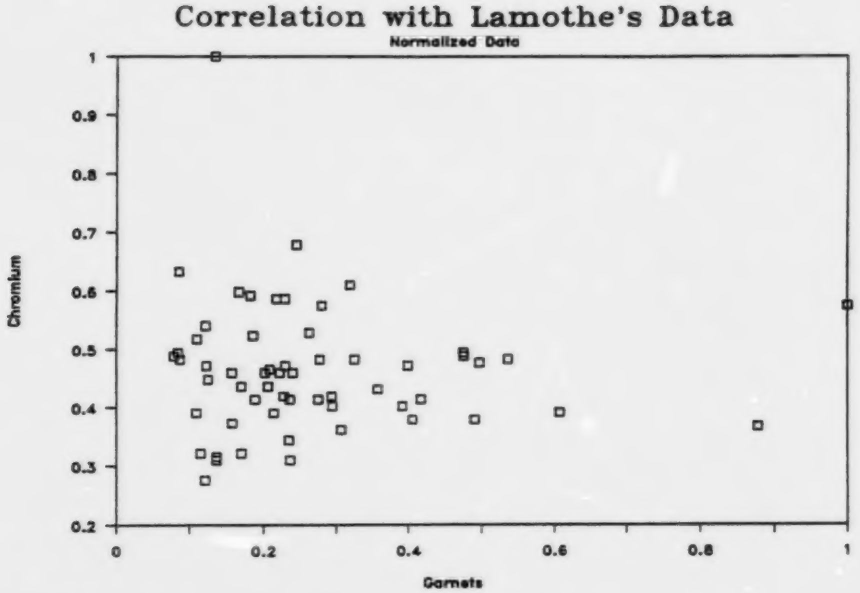


FIGURE 20: Correlation with Lamothe's (1990) data: Garnet vs. Cr

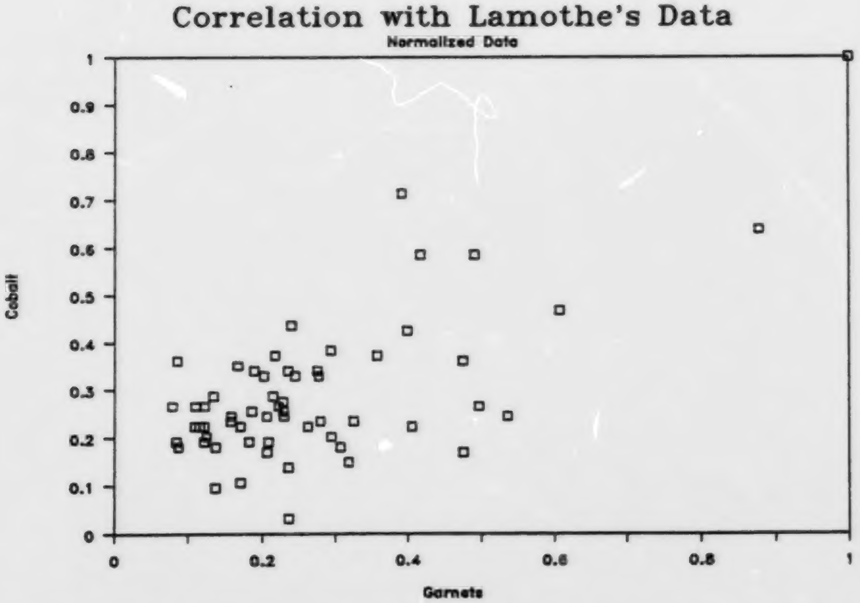


FIGURE 21: Correlation with Lamothe's (1990) data: Garnet vs. Co

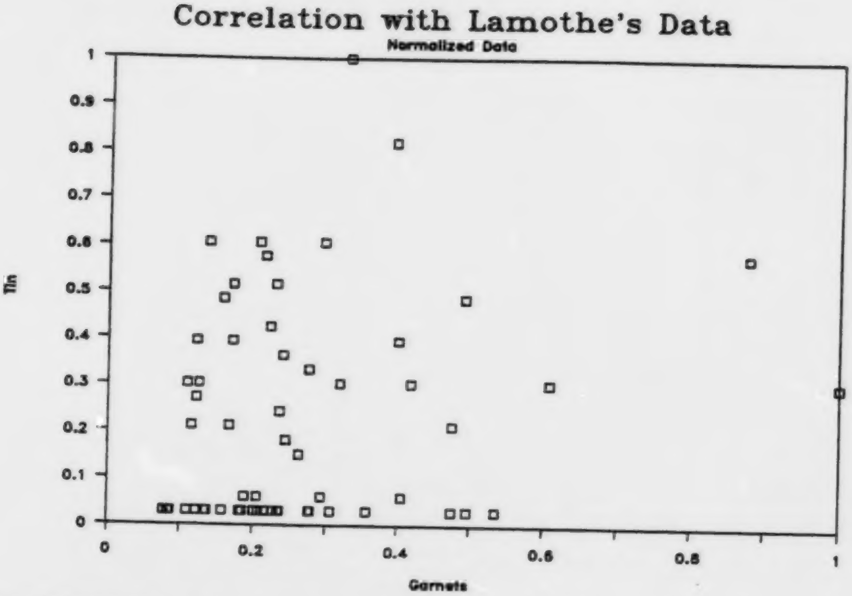


FIGURE 22: Correlation with Lamothe's (1990) data: Garnet vs. Sn

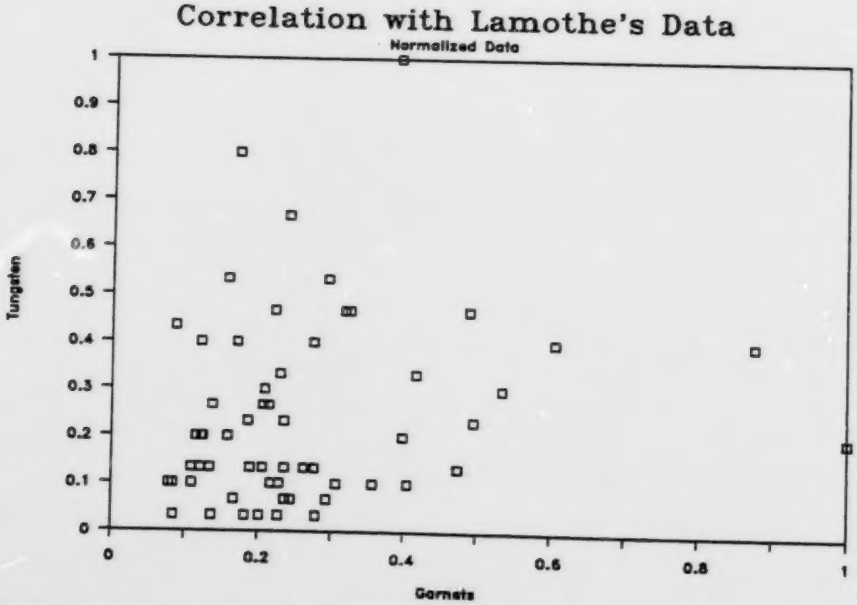


FIGURE 23: Correlation with Lamothe's (1990) data: Garnet vs. W

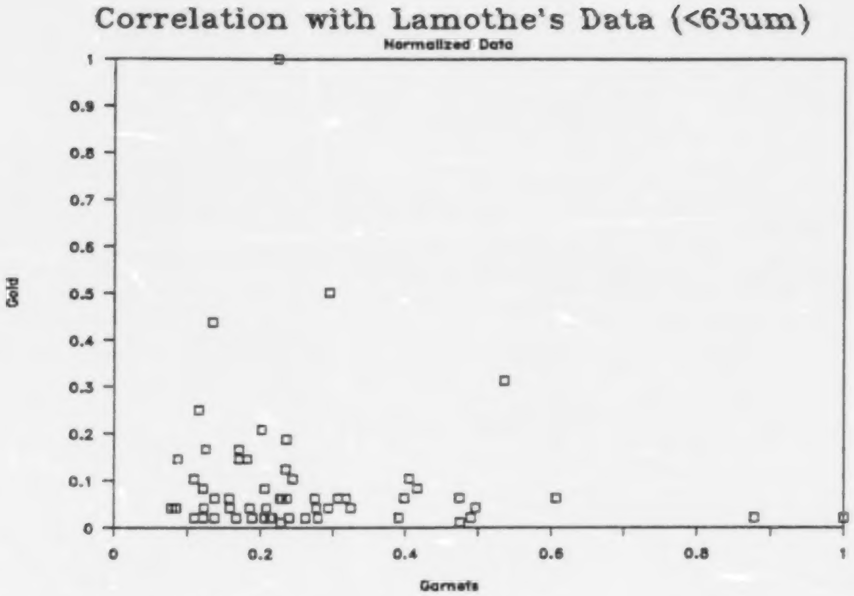


FIGURE 24: Correlation with Lamothe's (1990) data: Garnet vs. Au

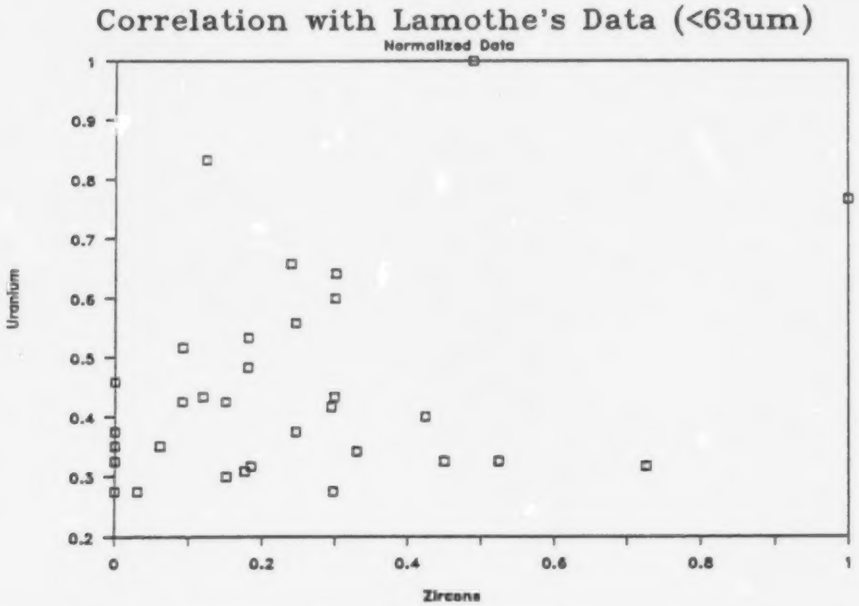


FIGURE 25: Correlation with Lamothe's (1990) data: Zircon vs. U

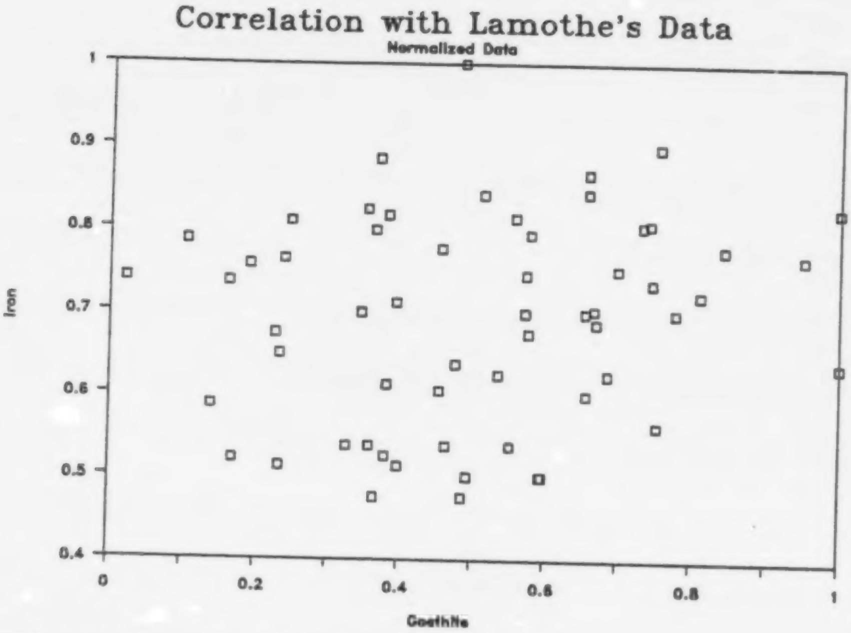


FIGURE 26: Correlation with Lamothe's (1990) data: Goethite vs. Fe

6.0 CONCLUSIONS

A study of the heavy mineral fraction in the tills from the Todd Mountain area, Central New Brunswick has shown that two geological units of interest may be readily traced using specific indicator minerals.

The Ordivician age metasedimentary unit which contains the known Todd Mountain tin and tungsten occurrence can be traced using whole garnets and garnet aggregates (coticules). When the combined data from these two indicators is contoured, an excellent correlation exists between the metasedimentary horizon and the contour maximums. This may prove to be useful in mapping this unit which shows potential for containing further Sn, W, and other base metal occurrences associated with the northwest-southeast set of fractures which crosscut the area.

Zircon, which is a common accessory mineral in granites, has proven to be a good indicator of the Trout Lake pluton. Although the concentration of zircon in the tills of the area is high, it is still a very suitable tracer mineral for the granitic body.

Fourteen samples contained grains which were optically identified as possible gold or electrum. Gold and electrum may be associated with the Sn, W, and other base metal vein mineralization crosscutting the Todd Mountain horizon. Further investigation is required using electron microbeam techniques to confirm these identifications.

Good correlations were observed between individual element assays performed by Lamothe (1990) and several of the heavy minerals identified in this study. The relationships were in support of co-geneity rather than elemental enrichment of particular minerals. Garnets representing the Todd Mountain horizon were found to show good correlations with Lamothe's (1990) base metal analyses.

Local topography appears to have exerted considerable control on the glacial processes of the area. The topographic lows are characterized by flat evenly spaced contour intervals for the indicator minerals. The topographic highs provide the best opportunity for glacial action to create distinctive dispersal plumes. It is also believed that the ridges may be acting as sites for the mixing of tills as the ice passes over them. This was apparent in the mineral relationships with topography.

Actual distances of physical glacial transport are short. Mineral dispersal plumes may be better suited for geological mapping, rather than mineral exploration, since they are on the order of several hundred meters to a maximum of approximately three kilometers.

If the heavy mineral fraction of the tills is to be exploited for mineral exploration, then it is recommended that the survey be carried out on tight, closely spaced grids. Sample grid centers should not be spaced more than 100 to 250 meters apart in order to accurately access dispersal characteristics.

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APPENDIX I : METHODOLOGY

1. Wet Sieving

a. The bulk sample was weighed.

b. The sample was mixed with water in a container. The sample bag was throughly washed and the material was added to the container. c. The sample was poured into a vibrating wet sieve apparatus. Two sieves were used: 1 mm and 2 mm mesh. These removed the pebbles and coarse sand. The lower pan had a run off hose which carried away the clay fraction in suspension. The lid of the apparatus had a water jet spraying down on the sample.

d. The sample was run for 10 minutes with the vibration dial on maximum.

e. The machine was shut off and the upper two pan were removed and dumped into waste pails.

f. The bottom pan with the silt and fine sand fraction was carefully washed into a plastic container.

2. Gold Wheel (Hound)

a. The gold wheel was turned on and the water flow was started.

b. The silt-sand fraction from the wet sieve was poured into the lower portion of the gold wheel.

c. The water source was adjusted until only a fine line of material travelled along the spiral grooves and down the center hole in the collection pail.

d. The wheel was shut off when the material being passed through to the pail consisted mostly of quartz and feldspar grains.

e. The collection pail was removed and the contents were washed into a foil drying pan.

f. The contents of the pan were oven dried and then packaged.

3. Gravity (Shaker) Table

a. The heavy fraction from the gold wheel was placed into a small beaker and mixed with water.

b. The mixture was poured onto the shake table.

c. The shaker table was turned on and the material was observed closely as it separated along the inner trough of the table.

d. The table was shut off when a fine dark line of material remained.

e. The coarse light fraction that was carried off the table first was washed out of the collection container into a foil pan and placed in the drying oven.

f. The fine heavy fraction on the table was carefully washed down into another collection container. This was then transferred to a foil pan and also placed in the drying oven.

g. Once the materials were dried they were packaged and labelled.

4. Heavy Liquid Procedures

4a. Heavy Liquid Separations

a. The centrifuge tubes (six were done in each individual run) were filled about half way with the particular heavy liquid being used (either bromoform or tetrabromoethane (see section 3.1.4). This was done under a fume hood.

b. The heavy fraction from the shaker table separation were poured into the tubes and an initial separation was observed.

c. A rubber stopper was placed into the top of each tube to prevent problems with fumes outside of the fume hood.

d. The tubes were placed in a centrifuge and run at 1000 rpm for 10 minutes.

e. The samples were removed from the centrifuge and the rubber stoppers were carefully taken out under the fume hood.

f. A plunger with a small plastic stopper was inserted into the tube to block off the lower neck.

g. The float and heavy liquid were poured off into a funnel which was fitted through a rubber stopper into the mouth of a flask. A piece of filter paper was used in the funnel to catch the mineral grains. Two separate flasks were used. The first collected the pure heavy liquid, while the second was used for heavy liquid and acetone washings.

h. The plastic stopper was removed from the lower neck of the centrifuge tube once the upper portion had throughly dried. The filters in the funnels were changed and the heavy material in the lower bulb of the centrifuge tube was poured out and washed.

i. The filters containing the heavies and lights were left under the fume hood for at least 48 hours to air out.

j. The heavy fraction was then bottled and weighed.

4.b Heavy Liquid Recovery

a. The mixture of heavy liquid and acetone was poured from the flask into an open beaker. The beaker was left uncovered under the fume hood for several days.

b. When the acetone had sufficiently evaporated off, the residual heavy liquid was filtered and then poured into a clean beaker.

c. The specific gravity of the recycled heavy liquid was estimated using plastic pellets with known specific gravities. They were systematically dropped into the beaker until one was observed to remain suspended in the liquid.

d. If the specific gravity was too low (<2.8 for the bromoform and <3.1 for the tetrabromoethane), it was left under the fume hood in the open beaker for another period of time.

5. Magnetic Separation

a. The heavy mineral fraction from the heavy liquid separation was spread out on a sheet of paper.

b. A hand held magnetic plunger was dragged through the material several times. The load of magnetic minerals captured were deposited on a second sheet of paper.

c. The magnetic material on the second sheet of paper were re-separated by the same method.

d. The residual from the second separation was recombined with the residual from the original sample.

e. Both the magnetic separate and magnetic-free sample were bottled and weighed.

6. X-ray Diffraction Analysis

All samples tested were prepared as smear mounts. The procedure followed in their preparation was:

a. A small amount (0.XX grams) of sample was placed into a mortar and mixed with acetone.

b. The material was ground with the pestle until a fine suspension was formed. This indicated the material was $\approx < 10\ \mu m$.

c. The suspension was poured onto a glass slide and allowed to settle into a thin layer.

d. The dried slide was labelled and then run on the x-ray diffractometer.

e. The samples were scanned over a range of 3 to 60° 2Θ. A potential of 40 KeV with a current of 20 mA was used. The diffractometer was equipped with a copper source with a graphite monochromator.

f. The d-spacing from the resulting profiles were interpreted using the search software µPDSM.

APPENDIX II: INITIAL SAMPLE WEIGHTS AND MAGNETITE

Number	Sample #	Initial Sample Wt (g)	Heavies (no Mte) (g)	Wt of Magnetite (g)	Number	Sample #	Initial Sample Wt (g)	Heavies (no Mte) (g)	Wt of Magnetite (g)
1	316	541	0.64	0.12	33	5201+	829	2.1	0.44
2	5034-C	2230	0.82	0.22	34	5200-C	2518	0.71	0.13
3	321-1	967	0.63	0.16	35	260-1	1510	0.77	0.19
4	5033-C	956	0.48	0.13	36	261	462	0.16	0.01
5	322-1	992	0.54	0.2	37	225	119	0.56	0.15
6	219-1	1368	0.67	0.2	38	272-1	1809	0.53	0.12
7	5035-C	2604	0.87	0.54	39	5203-C	2644	1.25	0.39
8	5112-C	2342	0.58	0.16	40	5202-C	2036	0.77	0.27
9	5113-C	1930	0.61	0.15	41	280-1	331	0.52	0
10	5114-C	2210	0.84	0.11	42	262-1	876	0.44	0.05
11	5104-C	2510	0.62	0.12	43	285	206	0.19	0
12	269-1	949	0.63	0.22	44	275	667	0.32	0.03
13	268-1	1182	0.56	0.17	45	R215	1072	0.41	0.06
14	221-1	2029	0.38	0.04	46	276-1	1319	1.54	0.18
15	5032-C	1216	0.49	0.14	47	277-1	766	0.4	0
16	5100-C	2297	1.69	0.41	48	R232	775	0.4	0.14
17	329-1	1067	0.54	0	49	5018-C	2004	0.58	0.08
18	R328	1370	0.44	0.02	50	288-1	817	0.32	0.01
19	610-1	874	0.37	0.1	51	235-1	1356	1.21	0.12
20	274-1	1421	0.57	0.1	52	5206-C	1845	1.42	0.06
21	347	814	0.43	0.03	53	5205-C	2612	0.41	0.02
22	614-1	1051	0.7	0.14	54	234-1	1890	0.98	0.23
23	5101-C	2113	1.41	0.25	55	5021-C	2184	0.45	0.04
24	615	703	0.26	0	56	5022-C	1942	0.48	0.05
25	5031-1	1085	0.4	0.06	57	5023-C	1966	0.44	0.05
26	264	445	0.19	0.09	58	5024-C	1761	0.36	0.05
27	270-1	1146	0.64	0.11	59	5025-C	1417	0.73	0.06
28	5102-C	3055	1.26	0.39	60	5027-C	1899	0.57	0.02
29	5103-C	2585	1.64	0.27	61	233-1	1192	1.06	0.52
30	273-1	580	0.32	0.01	62	213-1	1612	0.78	0.15
			0.5	0.04	63	296	1204	0.27	0.04

APPENDIX III: RAW SAMPLE COUNT DATA

MINERAL	316 1	5034-C 2	321-1 3	5033-C 4	322-1 5	5035-C 7
tourmaline	0	0	0	0	0	0
goeth/hem/limon	106	22	49	23	65	52
ilm/mag/rut	19	61	54	36	43	57
clear garnet	11	17	16	20	20	25
amphibole	18	14	3	29	12	22
unk/other trans	57	74	54	69	49	39
clear zircon	4	8	9	7	7	9
sillim/fibrol	0	1	2	2	2	0
unk/other opaq	35	50	58	34	39	45
?green garnet	0	4	2	0	0	0
garnet aggreg	4	2	9	34	16	3
epidote group	0	0	0	0	0	0
zoned zircon	1	2	1	2	3	4
TOTAL:	255	255	257	256	256	256

MINERAL	316 1	5034-C 2	321-1 3	5033-C 4	322-1 5	5035-C 7
tourmaline	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
goeth/hem/limon	41.6%	8.6%	19.1%	9.0%	25.4%	20.3%
ilm/mag/rut	7.5%	23.9%	21.0%	14.1%	16.8%	22.3%
clear garnet	4.3%	6.7%	6.2%	7.8%	7.8%	9.8%
amphibole	7.1%	5.5%	1.2%	11.3%	4.7%	8.6%
unk/other trans	22.4%	29.0%	21.0%	27.0%	19.1%	15.2%
clear zircon	1.6%	3.1%	3.5%	2.7%	2.7%	3.5%
sillim/fibrol	0.0%	0.4%	0.8%	0.8%	0.8%	0.0%
unk/other opaq	13.7%	19.6%	22.6%	13.3%	15.2%	17.6%
?green garnet	0.0%	1.6%	0.8%	0.0%	0.0%	0.0%
garnet aggreg	1.6%	0.8%	3.5%	13.3%	6.3%	1.2%
epidote group	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
zoned zircon	0.4%	0.8%	0.4%	0.8%	1.2%	1.6%
TOTAL:	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

APPENDIX III: RAW SAMPLE COUNT DATA

						Adjusted
MINERAL	5112-C	5113-C	5114-C	269-1	268-1	221-1
	8	9	10	12	13	14
tourmaline	0	0	0	0	1	1
goeth/hem/limon	100	51	78	31	32	70
ilm/mag/rut	32	54	39	52	40	11
clear garnet	17	17	15	22	22	25
amphibole	23	32	25	15	24	23
unk/other trans	47	43	33	77	70	66
clear zircon	4	6	7	8	6	35
sillim/fibrol	1	0	0	0	0	2
unk/other opaq	31	47	53	39	29	30
?green garnet	0	0	0	1	2	0
garnet aggreg	1	8	4	6	29	8
epidote group	0	0	0	0	0	0
zoned zircon	1	1	1	0	4	0
TOTAL:	257	259	255	251	258	270

						Adjusted
MINERAL	5112-C	5113-C	5114-C	269-1	268-1	221-1
	8	9	10	12	13	14
tourmaline	0.0%	0.0%	0.0%	0.0%	0.4%	0.4%
goeth/hem/limon	38.9%	19.7%	30.6%	12.4%	12.4%	25.9%
ilm/mag/rut	12.5%	20.8%	15.3%	20.7%	15.5%	4.1%
clear garnet	6.6%	6.6%	5.9%	8.8%	8.5%	9.3%
amphibole	8.9%	12.4%	9.8%	6.0%	9.3%	8.5%
unk/other trans	18.3%	16.6%	12.9%	30.7%	27.1%	24.4%
clear zircon	1.6%	2.3%	2.7%	3.2%	2.3%	13.0%
sillim/fibrol	0.4%	0.0%	0.0%	0.0%	0.0%	0.7%
unk/other opaq	12.1%	18.1%	20.8%	15.5%	11.2%	11.1%
?green garnet	0.0%	0.0%	0.0%	0.4%	0.8%	0.0%
garnet aggreg	0.4%	3.1%	1.6%	2.4%	11.2%	3.0%
epidote group	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
zoned zircon	0.4%	0.4%	0.4%	0.0%	1.6%	0.0%
TOTAL:	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

APPENDIX III: RAW SAMPLE COUNT DATA

MINERAL	5032-C 15	5100-C 16	329-1 17	R328 18	610-1 19	274-1 20
tourmaline	5	1	0	0	3	1
goeth/hem/limon	79	89	89	66	101	79
ilm/mag/rut	14	23	32	32	5	23
clear garnet	19	29	16	11	27	19
amphibole	19	15	14	23	10	12
unk/other trans	71	33	36	49	39	87
clear zircon	4	3	5	1	0	0
sillim/fibrol	4	0	1	0	2	4
unk/other opaq	32	34	32	37	24	12
?green garnet	1	2	1	3	1	4
garnet aggreg	1	17	27	28	30	8
epidote group	1	2	1	0	2	0
zoned zircon	9	7	1	1	0	0
TOTAL:	259	255	255	251	244	249

MINERAL	5032-C 15	5100-C 16	329-1 17	R328 18	610-1 19	274-1 20
tourmaline	1.9%	0.4%	0.0%	0.0%	1.2%	0.4%
goeth/hem/limon	30.5%	34.9%	34.9%	26.3%	41.4%	31.7%
ilm/mag/rut	5.4%	9.0%	12.5%	12.7%	2.0%	9.2%
clear garnet	7.3%	11.4%	6.3%	4.4%	11.1%	7.6%
amphibole	7.3%	5.9%	5.5%	9.2%	4.1%	4.8%
unk/other trans	27.4%	12.9%	14.1%	19.5%	16.0%	34.9%
clear zircon	1.5%	1.2%	2.0%	0.4%	0.0%	0.0%
sillim/fibrol	1.5%	0.0%	0.4%	0.0%	0.8%	1.6%
unk/other opaq	12.4%	13.3%	12.5%	14.7%	9.8%	4.8%
?green garnet	0.4%	0.8%	0.4%	1.2%	0.4%	1.6%
garnet aggreg	0.4%	6.7%	10.6%	11.2%	12.3%	3.2%
epidote group	0.4%	0.8%	0.4%	0.0%	0.8%	0.0%
zoned zircon	3.5%	2.7%	0.4%	0.4%	0.0%	0.0%

APPENDIX III: RAW SAMPLE COUNT DATA

MINERAL	347	614-1	5101-1	5031-1	264	270-1
	21	22	23	25	26	27
tourmaline	1	0	0	1	0	3
goeth/hem/limon	52	14	61	69	45	53
ilm/mag/rut	33	9	24	22	9	8
clear garnet	13	48	29	14	14	25
amphibole	14	0	6	11	7	9
unk/other trans	76	3	44	55	101	38
clear zircon	0	0	6	7	2	9
sillim/fibrol	2	0	0	3	0	3
unk/other opaq	26	1	25	32	15	77
?green garnet	2	0	2	3	10	1
garnet aggreg	34	177	51	33	54	13
epidote group	3	0	2	0	0	3
zoned zircon	0	0	1	3	2	8
TOTAL:	256	252	251	253	259	250

MINERAL	347	614-1	5101-1	5031-1	264	270-1
	21	22	23	25	26	27
tourmaline	0.4%	0.0%	0.0%	0.4%	0.0%	1.2%
goeth/hem/limon	20.3%	5.6%	24.3%	27.3%	17.4%	21.2%
ilm/mag/rut	12.9%	3.6%	9.6%	8.7%	3.5%	3.2%
clear garnet	5.1%	19.0%	11.6%	5.5%	5.4%	10.0%
amphibole	5.5%	0.0%	2.4%	4.3%	2.7%	3.6%
unk/other trans	29.7%	1.2%	17.5%	21.7%	39.0%	15.2%
clear zircon	0.0%	0.0%	2.4%	2.8%	0.8%	3.6%
sillim/fibrol	0.8%	0.0%	0.0%	1.2%	0.0%	1.2%
unk/other opaq	10.2%	0.4%	10.0%	12.6%	5.8%	30.8%
?green garnet	0.8%	0.0%	0.8%	1.2%	3.9%	0.4%
garnet aggreg	13.3%	70.2%	20.3%	13.0%	20.8%	5.2%
epidote group	1.2%	0.0%	0.8%	0.0%	0.0%	1.2%
zoned zircon	0.0%	0.0%	0.4%	1.2%	0.8%	3.2%
TOTAL:	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

APPENDIX III: RAW SAMPLE COUNT DATA

MINERAL	5102-C 28	5103-C 29	273-1 30	5029-C 31	5028-C 32	5201+ 33
tourmaline	2	0	0	0	1	1
goeth/hem/limon	99	100	67	75	61	26
ilm/mag/rut	11	41	17	14	41	80
clear garnet	33	27	10	42	31	86
amphibole	19	2	4	3	15	16
unk/other trans	27	26	59	14	35	20
clear zircon	4	1	3	3	4	8
sillim/fibrol	3	0	0	2	1	0
unk/other opaq	21	9	11	16	18	10
?green garnet	0	1	34	0	6	0
garnet aggreg	29	39	29	79	38	7
epidote group	2	2	0	0	1	1
zoned zircon	1	4	21	5	0	2
TOTAL:	251	252	255	253	252	257

MINERAL	5102-C 28	5103-C 29	273-1 30	5029-C 31	5028-C 32	5201+ 33
tourmaline	0.8%	0.0%	0.0%	0.0%	0.4%	0.4%
goeth/hem/limon	39.4%	39.7%	26.3%	29.6%	24.2%	10.1%
ilm/mag/rut	4.4%	16.3%	6.7%	5.5%	16.3%	31.1%
clear garnet	13.1%	10.7%	3.9%	16.6%	12.3%	33.5%
amphibole	7.6%	0.8%	1.6%	1.2%	6.0%	6.2%
unk/other trans	10.8%	10.3%	23.1%	5.5%	13.9%	7.8%
clear zircon	1.6%	0.4%	1.2%	1.2%	1.6%	3.1%
sillim/fibrol	1.2%	0.0%	0.0%	0.8%	0.4%	0.0%
unk/other opaq	8.4%	3.6%	4.3%	6.3%	7.1%	3.9%
?green garnet	0.0%	0.4%	13.3%	0.0%	2.4%	0.0%
garnet aggreg	11.6%	15.5%	11.4%	31.2%	15.1%	2.7%
epidote group	0.8%	0.8%	0.0%	0.0%	0.4%	0.4%
zoned zircon	0.4%	1.6%	8.2%	2.0%	0.0%	0.8%
TOTAL:	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

APPENDIX III: RAW SAMPLE COUNT DATA

MINERAL	5200-C	260-1	261	225	272-1	5203-C
	34	35	36	37	38	39
tourmaline	0	0	0	0	2	1
goeth/hem/limon	107	89	19	79	64	88
ilm/mag/rut	18	4	52	20	31	31
clear garnet	23	32	25	14	31	30
amphibole	4	7	4	11	13	9
unk/other trans	53	39	63	67	56	31
clear zircon	1	0	9	2	3	2
sillim/fibrol	2	4	1	5	0	2
unk/other opaq	22	16	26	15	28	24
?green garnet	0	1	1	0	2	3
garnet aggreg	12	57	48	32	22	23
epidote group	1	0	3	3	0	2
zoned zircon	5	1	6	2	7	7
TOTAL:	248	250	257	250	259	253

MINERAL	5200-C	260-1	261	225	272-1	5203-C
	34	35	36	37	38	39
tourmaline	0.0%	0.0%	0.0%	0.0%	0.8%	0.4%
goeth/hem/limon	43.1%	35.6%	7.4%	31.6%	24.7%	34.8%
ilm/mag/rut	7.3%	1.6%	20.2%	8.0%	12.0%	12.3%
clear garnet	9.3%	12.8%	9.7%	5.6%	12.0%	11.9%
amphibole	1.6%	2.8%	1.6%	4.4%	5.0%	3.6%
unk/other trans	21.4%	15.6%	24.5%	26.8%	21.6%	12.3%
clear zircon	0.4%	0.0%	3.5%	0.8%	1.2%	0.8%
sillim/fibrol	0.8%	1.6%	0.4%	2.0%	0.0%	0.8%
unk/other opaq	8.9%	6.4%	10.1%	6.0%	10.8%	9.5%
?green garnet	0.0%	0.4%	0.4%	0.0%	0.8%	1.2%
garnet aggreg	4.8%	22.8%	18.7%	12.8%	8.5%	9.1%
epidote group	0.4%	0.0%	1.2%	1.2%	0.0%	0.8%
zoned zircon	2.0%	0.4%	2.3%	0.8%	2.7%	2.8%
TOTAL:	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

APPENDIX III:RAW SAMPLE COUNT DATA

MINERAL	5202-C	280-1	262-1	285	275	R215
	40	41	42	43	44	45
tourmaline	0	0	0	1	0	0
goeth/hem/limon	94	77	51	137	103	51
ilm/mag/rut	47	8	26	2	15	26
clear garnet	17	54	12	9	21	21
amphibole	15	4	7	10	8	3
unk/other trans	20	16	92	38	48	45
clear zircon	6	0	2	1	0	11
sillim/fibrol	1	0	1	5	0	0
unk/other opaq	35	8	21	21	14	22
?green garnet	0	0	1	2	1	1
garnet aggreg	14	83	44	19	42	67
epidote group	0	0	1	6	0	0
zoned zircon	4	3	4	7	5	5
TOTAL:	253	253	262	258	257	252

MINERAL	5202-C	280-1	262-1	285	275	R215
	40	41	42	43	44	45
tourmaline	0.0%	0.0%	0.0%	0.4%	0.0%	0.0%
goeth/hem/limon	37.2%	30.4%	19.5%	53.1%	40.1%	20.2%
ilm/mag/rut	18.6%	3.2%	9.9%	0.8%	5.8%	10.3%
clear garnet	6.7%	21.3%	4.6%	3.5%	8.2%	8.3%
amphibole	5.9%	1.6%	2.7%	3.9%	3.1%	1.2%
unk/other trans	7.9%	6.3%	35.1%	14.7%	18.7%	17.9%
clear zircon	2.4%	0.0%	0.8%	0.4%	0.0%	4.4%
sillim/fibrol	0.4%	0.0%	0.4%	1.9%	0.0%	0.0%
unk/other opaq	13.8%	3.2%	8.0%	8.1%	5.4%	8.7%
?green garnet	0.0%	0.0%	0.4%	0.8%	0.4%	0.4%
garnet aggreg	5.5%	32.8%	16.8%	7.4%	16.3%	26.6%
epidote group	0.0%	0.0%	0.4%	2.3%	0.0%	0.0%
zoned zircon	1.6%	1.2%	1.5%	2.7%	1.9%	2.0%
TOTAL:	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

APPENDIX III: RAW SAMPLE COUNT DATA

MINERAL	276-1	277-1	R232	5018-C	288-1	235-1
	46	47	48	49	50	51
tourmaline	0	0	0	4	1	2
goeth/hem/limon	30	134	103	89	75	77
ilm/mag/rut	2	4	37	21	15	3
clear garnet	153	9	43	21	37	66
amphibole	0	4	8	13	9	1
unk/other trans	11	45	26	47	64	16
clear zircon	0	2	4	4	0	2
sillim/fibrol	0	3	0	2	0	0
unk/other opaq	2	30	18	18	8	27
?green garnet	9	3	0	1	5	4
garnet aggreg	43	17	11	30	37	44
epidote group	0	1	0	1	1	3
zoned zircon	0	0	7	0	3	6
TOTAL:	250	252	257	251	255	251

MINERAL	276-1	277-1	R232	5018-C	288-1	235-1
	46	47	48	49	50	51
tourmaline	0.0%	0.0%	0.0%	1.6%	0.4%	0.8%
goeth/hem/limon	12.0%	53.2%	40.1%	35.5%	29.4%	30.7%
ilm/mag/rut	0.8%	1.6%	14.4%	8.4%	5.9%	1.2%
clear garnet	61.2%	3.6%	16.7%	8.4%	14.5%	26.3%
amphibole	0.0%	1.6%	3.1%	5.2%	3.5%	0.4%
unk/other trans	4.4%	17.9%	10.1%	18.7%	25.1%	6.4%
clear zircon	0.0%	0.8%	1.6%	1.6%	0.0%	0.8%
sillim/fibrol	0.0%	1.2%	0.0%	0.8%	0.0%	0.0%
unk/other opaq	0.8%	11.9%	7.0%	7.2%	3.1%	10.8%
?green garnet	3.6%	1.2%	0.0%	0.4%	2.0%	1.6%
garnet aggreg	17.2%	6.7%	4.3%	12.0%	14.5%	17.5%
epidote group	0.0%	0.4%	0.0%	0.4%	0.4%	1.2%
zoned zircon	0.0%	0.0%	2.7%	0.0%	1.2%	2.4%
TOTAL:	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

APPENDIX III: RAW SAMPLE COUNT DATA

MINERAL	5206-C	5205-C	234-1	5021-C	5022-C	5023-C
	52	53	54	55	56	57
tourmaline	0	1	0	1	2	1
goeth/hem/limon	79	3	46	32	88	50
ilm/mag/rut	13	33	14	41	23	19
clear garnet	29	45	9	37	23	14
amphibole	5	13	2	17	17	26
unk/other trans	29	56	73	66	50	79
clear zircon	1	2	2	3	0	2
sillim/fibrol	0	1	0	1	0	1
unk/other opaq	14	36	18	23	26	19
?green garnet	1	0	0	0	0	2
garnet aggreg	85	65	84	26	18	38
epidote group	0	1	0	2	3	0
zoned zircon	1	3	2	4	2	4
TOTAL:	257	259	250	253	252	255

MINERAL	5206-C	5205-C	234-1	5021-C	5022-C	5023-C
	52	53	54	55	56	57
tourmaline	0.0%	0.4%	0.0%	0.4%	0.8%	0.4%
goeth/hem/limon	30.7%	1.2%	18.4%	12.6%	34.9%	19.6%
ilm/mag/rut	5.1%	12.7%	5.6%	16.2%	9.1%	7.5%
clear garnet	11.3%	17.4%	3.6%	14.6%	9.1%	5.5%
amphibole	1.9%	5.0%	0.8%	6.7%	6.7%	10.2%
unk/other trans	11.3%	21.6%	29.2%	26.1%	19.8%	31.0%
clear zircon	0.4%	0.8%	0.8%	1.2%	0.0%	0.8%
sillim/fibrol	0.0%	0.4%	0.0%	0.4%	0.0%	0.4%
unk/other opaq	5.4%	13.9%	7.2%	9.1%	10.3%	7.5%
?green garnet	0.4%	0.0%	0.0%	0.0%	0.0%	0.8%
garnet aggreg	33.1%	25.1%	33.6%	10.3%	7.1%	14.9%
epidote group	0.0%	0.4%	0.0%	0.8%	1.2%	0.0%
zoned zircon	0.4%	1.2%	0.8%	1.6%	0.8%	1.6%
TOTAL:	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

APPENDIX III: RAW SAMPLE COUNT DATA

MINERAL	5024-C	5025-C	5027-C	233-1	213-1	296
	58	59	60	61	62	63
tourmaline	2	4	1	3	2	0
goeth/hem/limon	65	109	133	73	93	55
ilm/mag/rut	27	7	18	21	37	28
clear garnet	21	13	9	24	14	15
amphibole	28	9	9	29	15	8
unk/other trans	29	47	59	44	41	75
clear zircon	8	3	1	0	1	3
sillim/fibrol	0	3	1	5	2	2
unk/other opaq	43	28	15	24	22	23
?green garnet	1	1	1	1	0	2
garnet aggreg	28	16	11	25	24	42
epidote group	0	2	2	1	0	2
zoned zircon	1	1	3	6	4	7
TOTAL:	253	243	263	256	255	262

MINERAL	5024-C	5025-C	5027-C	233-1	213-1	296
	58	59	60	61	62	63
tourmaline	0.8%	1.6%	0.4%	1.2%	0.8%	0.0%
goeth/hem/limon	25.7%	44.9%	50.6%	28.5%	36.5%	21.0%
ilm/mag/rut	10.7%	2.9%	6.8%	8.2%	14.5%	10.7%
clear garnet	8.3%	5.3%	3.4%	9.4%	5.5%	5.7%
amphibole	11.1%	3.7%	3.4%	11.3%	5.9%	3.1%
unk/other trans	11.5%	19.3%	22.4%	17.2%	16.1%	28.6%
clear zircon	3.2%	1.2%	0.4%	0.0%	0.4%	1.1%
sillim/fibrol	0.0%	1.2%	0.4%	2.0%	0.8%	0.8%
unk/other opaq	17.0%	11.5%	5.7%	9.4%	8.6%	8.8%
?green garnet	0.4%	0.4%	0.4%	0.4%	0.0%	0.8%
garnet aggreg	11.1%	6.6%	4.2%	9.8%	9.4%	16.0%
epidote group	0.0%	0.8%	0.8%	0.4%	0.0%	0.8%
zoned zircon	0.4%	0.4%	1.1%	2.3%	1.6%	2.7%
TOTAL:	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

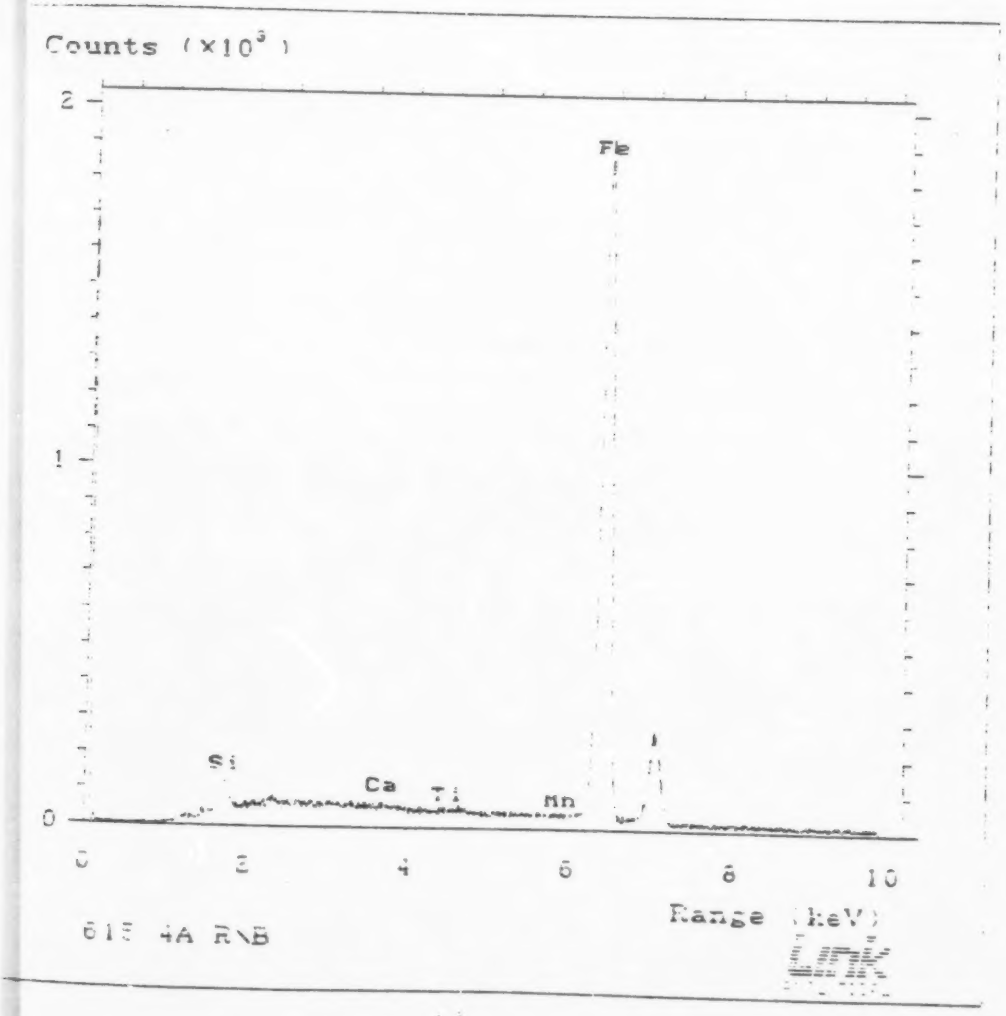
APPENDIX III: SUMMARY OF MODAL MINERAL ABUNDANCES

MINERAL		tourm	goeth	ilm	clr gar	amph	U/O tr	clr Zr	sill	U/O op	Iso gr	cot	epid	zon Zr	tot op	tot tr	tot Zr	tot gar
316	1	0.0%	41.6%	7.5%	4.3%	7.1%	22.4%	1.6%	0.0%	13.7%	0.0%	1.6%	0.0%	0.4%	62.7%	37.3%	2.0%	5.9%
5034-C	2	0.0%	8.6%	23.9%	6.7%	5.5%	29.0%	3.1%	0.4%	19.6%	1.6%	0.8%	0.0%	0.8%	52.2%	47.8%	3.9%	7.5%
321-1	3	0.0%	19.1%	21.0%	6.2%	1.2%	21.0%	3.5%	0.8%	22.6%	0.8%	3.5%	0.0%	0.4%	62.6%	37.4%	3.9%	9.7%
5033-C	4	0.0%	9.0%	14.1%	7.8%	11.3%	27.0%	2.7%	0.8%	13.3%	0.0%	13.3%	0.0%	0.8%	36.3%	63.7%	3.5%	21.1%
322-1	5	0.0%	25.4%	16.8%	7.8%	4.7%	19.1%	2.7%	0.8%	15.2%	0.0%	6.3%	0.0%	1.2%	57.4%	42.6%	3.9%	14.1%
219-1	6	0.0%	18.8%	9.0%	4.3%	8.2%	32.5%	4.7%	0.4%	15.3%	0.4%	5.5%	0.0%	0.8%	43.1%	56.8%	5.5%	9.8%
5035-C	7	0.0%	20.3%	22.3%	9.8%	8.6%	15.2%	3.5%	0.0%	17.6%	0.0%	1.2%	0.0%	1.6%	60.2%	39.8%	5.1%	10.9%
5112-C	8	0.0%	38.9%	12.5%	6.6%	8.9%	18.3%	1.6%	0.4%	12.1%	0.0%	0.4%	0.0%	0.4%	63.4%	36.6%	1.9%	7.0%
5113-C	9	0.0%	19.7%	20.8%	6.6%	12.4%	16.6%	2.3%	0.0%	18.1%	0.0%	3.1%	0.0%	0.4%	58.7%	41.3%	2.7%	9.7%
5114-C	10	0.0%	30.6%	15.3%	5.9%	9.8%	12.9%	2.7%	0.0%	20.8%	0.0%	1.6%	0.0%	0.4%	66.7%	33.3%	3.1%	7.5%
5104-C	11	0.8%	13.1%	11.5%	9.9%	10.7%	25.4%	4.0%	0.8%	16.3%	0.4%	6.7%	0.0%	0.4%	40.9%	59.1%	4.4%	16.6%
269-1	12	0.0%	12.4%	20.7%	8.8%	6.0%	30.7%	3.2%	0.0%	15.5%	0.4%	2.4%	0.0%	0.0%	48.6%	51.4%	3.2%	11.2%
268-1	13	0.4%	12.4%	15.5%	8.5%	9.3%	27.1%	2.3%	0.0%	11.2%	0.8%	11.2%	0.0%	1.6%	39.1%	61.2%	3.9%	19.8%
2211-1	14	0.4%	25.9%	4.1%	9.3%	8.5%	24.4%	13.0%	0.7%	11.1%	0.0%	3.0%	0.0%	0.0%	41.1%	59.3%	13.0%	12.2%
5032-C	15	1.9%	30.5%	5.4%	7.3%	7.3%	27.4%	1.5%	1.5%	12.4%	0.4%	0.4%	0.4%	3.5%	48.3%	51.7%	5.0%	7.7%
5100-C	16	0.4%	34.9%	9.0%	11.4%	5.9%	12.9%	1.2%	0.0%	13.3%	0.8%	6.7%	0.8%	2.7%	57.3%	42.7%	3.9%	18.0%
329-1	17	0.0%	34.9%	12.5%	6.3%	5.5%	14.1%	2.0%	0.4%	12.5%	0.4%	10.6%	0.4%	0.4%	60.0%	40.0%	2.4%	16.9%
R328	18	0.0%	26.3%	12.7%	4.4%	9.2%	19.5%	0.4%	0.0%	14.7%	1.2%	11.2%	0.0%	0.4%	53.8%	46.2%	0.8%	15.5%
610-1	19	1.2%	41.4%	2.0%	11.1%	4.1%	16.0%	0.0%	0.8%	9.8%	0.4%	12.3%	0.8%	0.0%	53.3%	46.7%	0.0%	23.4%
274-1	20	0.4%	31.7%	9.2%	7.6%	4.8%	34.9%	0.0%	1.6%	4.8%	1.6%	3.2%	0.0%	0.0%	45.8%	54.2%	0.0%	10.8%
347	21	0.4%	20.3%	12.9%	5.1%	5.5%	29.7%	0.0%	0.8%	10.2%	0.8%	13.3%	1.2%	0.0%	43.4%	56.6%	0.0%	18.4%
614-1	22	0.0%	5.6%	3.6%	19.0%	0.0%	1.2%	0.0%	0.0%	0.4%	0.0%	70.2%	0.0%	0.0%	9.5%	90.5%	0.0%	89.3%
5101-C	23	0.0%	24.3%	9.6%	11.6%	2.4%	17.5%	2.4%	0.0%	10.0%	0.8%	20.3%	0.8%	0.4%	43.8%	56.2%	2.8%	31.9%
615	24	0.0%	19.4%	9.1%	8.3%	3.2%	17.5%	1.6%	0.4%	5.2%	0.0%	34.1%	0.4%	0.8%	33.7%	66.3%	2.4%	42.4%
5031-1	25	0.4%	27.3%	8.7%	5.5%	4.3%	21.7%	2.8%	1.2%	12.6%	1.2%	13.0%	0.0%	1.2%	48.6%	51.4%	4.0%	18.6%
264	26	0.0%	17.4%	3.5%	5.4%	2.7%	39.0%	0.8%	0.0%	5.8%	3.9%	20.8%	0.0%	0.8%	26.6%	73.4%	1.5%	26.3%
270-1	27	1.2%	21.2%	3.2%	10.0%	3.6%	15.2%	3.6%	1.2%	30.8%	0.4%	5.2%	1.2%	3.2%	55.2%	44.8%	6.8%	15.2%
5102-C	28	0.8%	39.4%	4.4%	13.1%	7.6%	10.8%	1.6%	1.2%	8.4%	0.0%	11.6%	0.8%	0.4%	52.2%	47.8%	2.0%	24.7%
5103-C	29	0.0%	39.7%	16.3%	10.7%	0.8%	10.3%	0.4%	0.0%	3.6%	0.4%	15.5%	0.8%	1.6%	59.5%	40.5%	2.0%	26.2%
273-1	30	0.0%	26.3%	6.7%	3.9%	1.6%	23.1%	1.2%	0.0%	4.3%	13.3%	11.4%	0.0%	8.2%	37.3%	62.7%	9.4%	15.3%
5029-C	31	0.0%	29.6%	5.5%	16.6%	1.2%	5.5%	1.2%	0.8%	6.3%	0.0%	31.2%	0.0%	2.0%	41.5%	58.5%	3.2%	47.8%
5028-C	32	0.4%	24.2%	16.3%	12.3%	6.0%	13.9%	1.6%	0.4%	7.1%	2.4%	15.1%	0.4%	0.0%	47.6%	52.4%	1.6%	27.4%

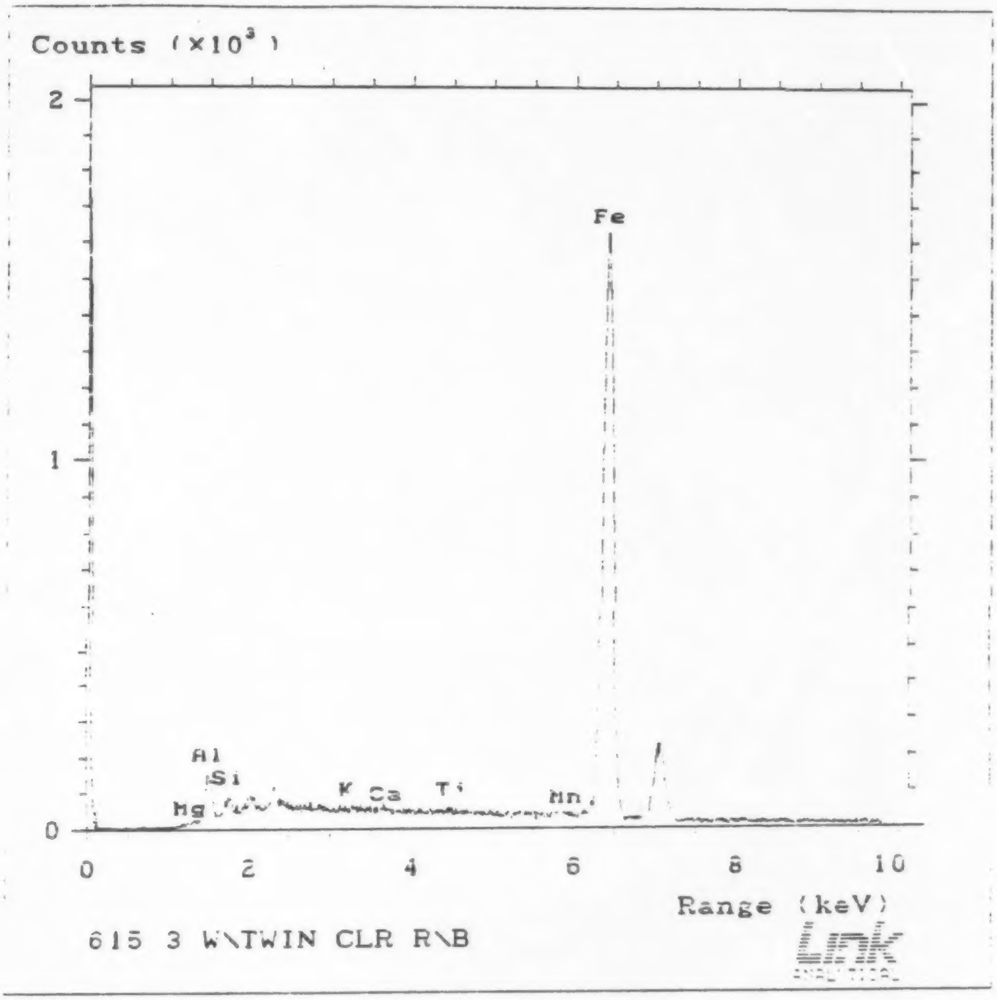
APPENDIX III: SUMMARY OF MODAL MINERAL ABUNDANCES

MINERAL		tourm	goeth	ilm	clr gar	amph	U/O tr	clr Zr	sill	U/O op	Iso gr	cot	epid	zon Zr	tot op	tot tr	tot Zr	tot gar
5201+	33	0.4%	10.1%	31.1%	33.5%	6.2%	7.8%	3.1%	0.0%	3.9%	0.0%	2.7%	0.4%	0.8%	45.1%	54.9%	3.9%	36.2%
5200-C	34	0.0%	43.1%	7.3%	9.3%	1.6%	21.4%	0.4%	0.8%	8.9%	0.0%	4.8%	0.4%	2.0%	59.3%	40.7%	2.4%	14.1%
260-1	35	0.0%	35.6%	1.6%	12.8%	2.8%	15.6%	0.0%	1.6%	6.4%	0.4%	22.8%	0.0%	0.4%	43.6%	56.4%	0.4%	35.6%
261	36	0.0%	7.4%	20.2%	9.7%	1.6%	24.5%	3.5%	0.4%	10.1%	0.4%	18.7%	1.2%	2.3%	37.7%	62.3%	5.8%	28.4%
225	37	0.0%	31.6%	8.0%	5.6%	4.4%	26.8%	0.8%	2.0%	6.0%	0.0%	12.8%	1.2%	0.8%	45.6%	54.4%	1.6%	18.4%
272-1	38	0.8%	24.7%	12.0%	12.0%	5.0%	21.6%	1.2%	0.0%	10.8%	0.8%	8.5%	0.0%	2.7%	47.5%	52.5%	3.9%	20.5%
5203-C	39	0.4%	34.8%	12.3%	11.9%	3.6%	12.3%	0.8%	0.8%	9.5%	1.2%	9.1%	0.8%	2.8%	56.5%	43.5%	3.6%	20.9%
5202-C	40	0.0%	37.2%	18.6%	6.7%	5.9%	7.9%	2.4%	0.4%	13.8%	0.0%	5.5%	0.0%	1.6%	69.6%	30.4%	4.0%	12.3%
280-1	41	0.0%	30.4%	3.2%	21.3%	1.6%	6.3%	0.0%	0.0%	3.2%	0.0%	32.8%	0.0%	1.2%	36.8%	63.2%	1.2%	54.2%
262-1	42	0.0%	19.5%	9.9%	4.6%	2.7%	35.1%	0.8%	0.4%	8.0%	0.4%	16.8%	0.4%	1.5%	37.4%	62.6%	2.3%	21.4%
285	43	0.4%	53.1%	0.8%	3.5%	3.9%	14.7%	0.4%	1.9%	8.1%	0.8%	7.4%	2.3%	2.7%	62.0%	38.0%	3.1%	10.9%
275	44	0.0%	40.1%	5.8%	8.2%	3.1%	18.7%	0.0%	0.0%	5.4%	0.4%	16.3%	0.0%	1.9%	51.4%	48.6%	1.9%	24.5%
R215	45	0.0%	20.2%	10.3%	8.3%	1.2%	17.9%	4.4%	0.0%	8.7%	0.4%	26.6%	0.0%	2.0%	39.3%	60.7%	6.3%	34.9%
276-1	46	0.0%	12.0%	0.8%	61.2%	0.0%	4.4%	0.0%	0.0%	0.8%	3.6%	17.2%	0.0%	0.0%	13.6%	86.4%	0.0%	78.4%
277-1	47	0.0%	53.2%	1.6%	3.6%	1.6%	17.9%	0.8%	1.2%	11.9%	1.2%	6.7%	0.4%	0.0%	66.7%	33.3%	0.8%	10.3%
R232	48	0.0%	40.1%	14.4%	16.7%	3.1%	10.1%	1.6%	0.0%	7.0%	0.0%	4.3%	0.0%	2.7%	61.5%	38.5%	4.3%	21.0%
5018-C	49	1.6%	35.5%	8.4%	8.4%	5.2%	18.7%	1.6%	0.8%	7.2%	0.4%	12.0%	0.4%	0.0%	51.0%	49.0%	1.6%	20.3%
288-1	50	0.4%	29.4%	5.9%	14.5%	3.5%	25.1%	0.0%	0.0%	3.1%	2.0%	14.5%	0.4%	1.2%	38.4%	61.6%	1.2%	29.0%
235-1	51	0.8%	30.7%	1.2%	26.3%	0.4%	6.4%	0.8%	0.0%	10.8%	1.6%	17.5%	1.2%	2.4%	42.6%	57.4%	3.2%	43.8%
5206-C	52	0.0%	30.7%	5.1%	11.3%	1.9%	11.3%	0.4%	0.0%	5.4%	0.4%	33.1%	0.0%	0.4%	41.2%	58.8%	0.8%	44.4%
5205-C	53	0.4%	1.2%	12.7%	17.4%	5.0%	21.6%	0.8%	0.4%	13.9%	0.0%	25.1%	0.4%	1.2%	27.8%	72.2%	1.9%	42.5%
234-1	54	0.0%	18.4%	5.6%	3.6%	0.8%	29.2%	0.8%	0.0%	7.2%	0.0%	33.6%	0.0%	0.8%	31.2%	68.8%	1.6%	37.2%
5021-C	55	0.4%	12.6%	16.2%	14.6%	6.7%	26.1%	1.2%	0.4%	9.1%	0.0%	10.3%	0.8%	1.6%	37.9%	62.1%	2.8%	24.9%
5022-C	56	0.8%	34.9%	9.1%	9.1%	6.7%	19.8%	0.0%	0.0%	10.3%	0.0%	7.1%	1.2%	0.8%	54.4%	45.6%	0.8%	16.3%
5023-C	57	0.4%	19.6%	7.5%	5.5%	10.2%	31.0%	0.8%	0.4%	7.5%	0.8%	14.9%	0.0%	1.6%	34.5%	65.5%	2.4%	20.4%
5024-C	58	0.8%	25.7%	10.7%	8.3%	11.1%	11.5%	3.2%	0.0%	17.0%	0.4%	11.1%	0.0%	0.4%	53.4%	46.6%	3.6%	19.4%
5025-C	59	1.6%	44.9%	2.9%	5.3%	3.7%	19.3%	1.2%	1.2%	11.5%	0.4%	6.6%	0.8%	0.4%	59.3%	40.7%	1.6%	11.9%
5027-C	60	0.4%	50.6%	6.8%	3.4%	3.4%	22.4%	0.4%	0.4%	5.7%	0.4%	4.2%	0.8%	1.1%	63.1%	36.9%	1.5%	7.6%
233-1	61	1.2%	28.5%	8.2%	9.4%	11.3%	17.2%	0.0%	2.0%	9.4%	0.4%	9.8%	0.4%	2.3%	46.1%	53.9%	2.3%	19.1%
213-1	62	0.8%	36.5%	14.5%	5.5%	5.9%	16.1%	0.4%	0.8%	8.6%	0.0%	9.4%	0.0%	1.6%	59.6%	40.4%	2.0%	14.9%
296	63	0.0%	21.0%	10.7%	5.7%	3.1%	28.6%	1.1%	0.8%	8.8%	0.8%	16.0%	0.8%	2.7%	40.5%	59.5%	3.8%	21.8%

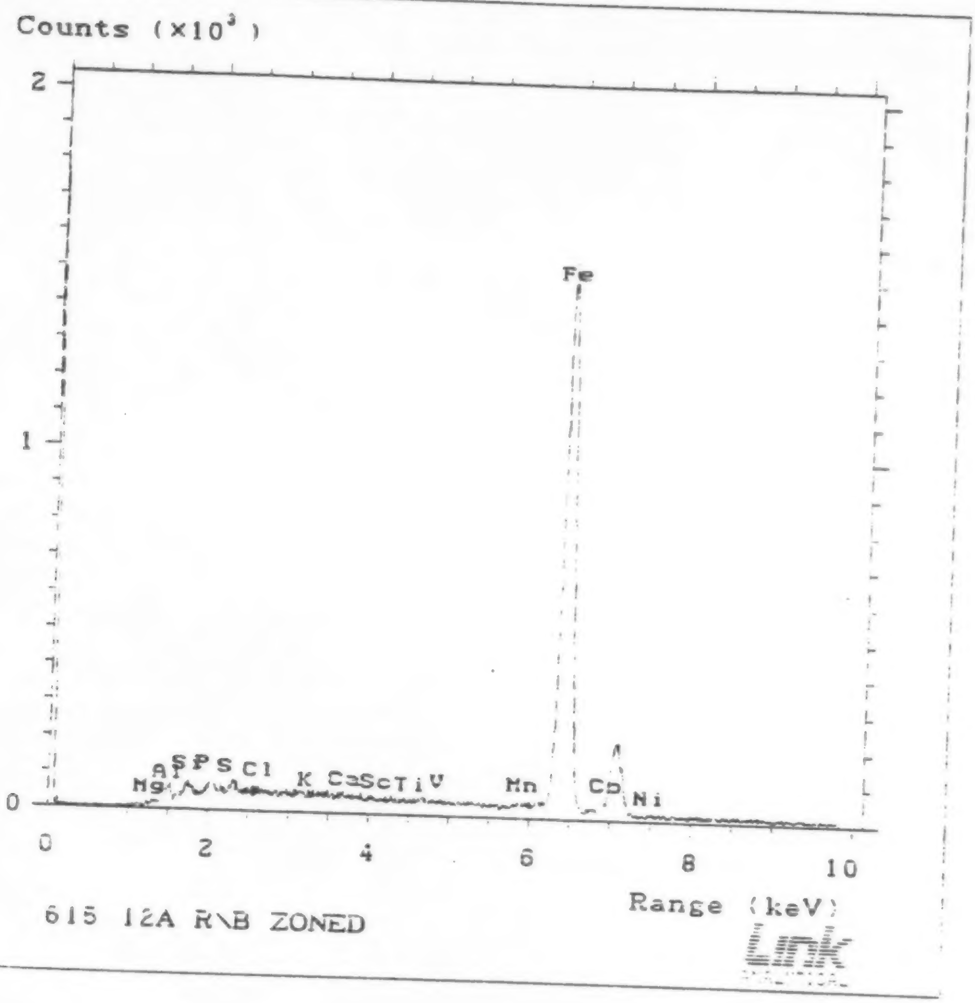
PLOT IV.1



PLOT IV.2


Counts (×10³)
2
1
0
Fe
Al
Si
Mg
K
Ca
Ti
Mn
0
2
4
6
8
10
Range (keV)
615 3 W\TWIN CLR R\B
Link
ANALYTICAL

PLOT IV.3


Counts (×10³)
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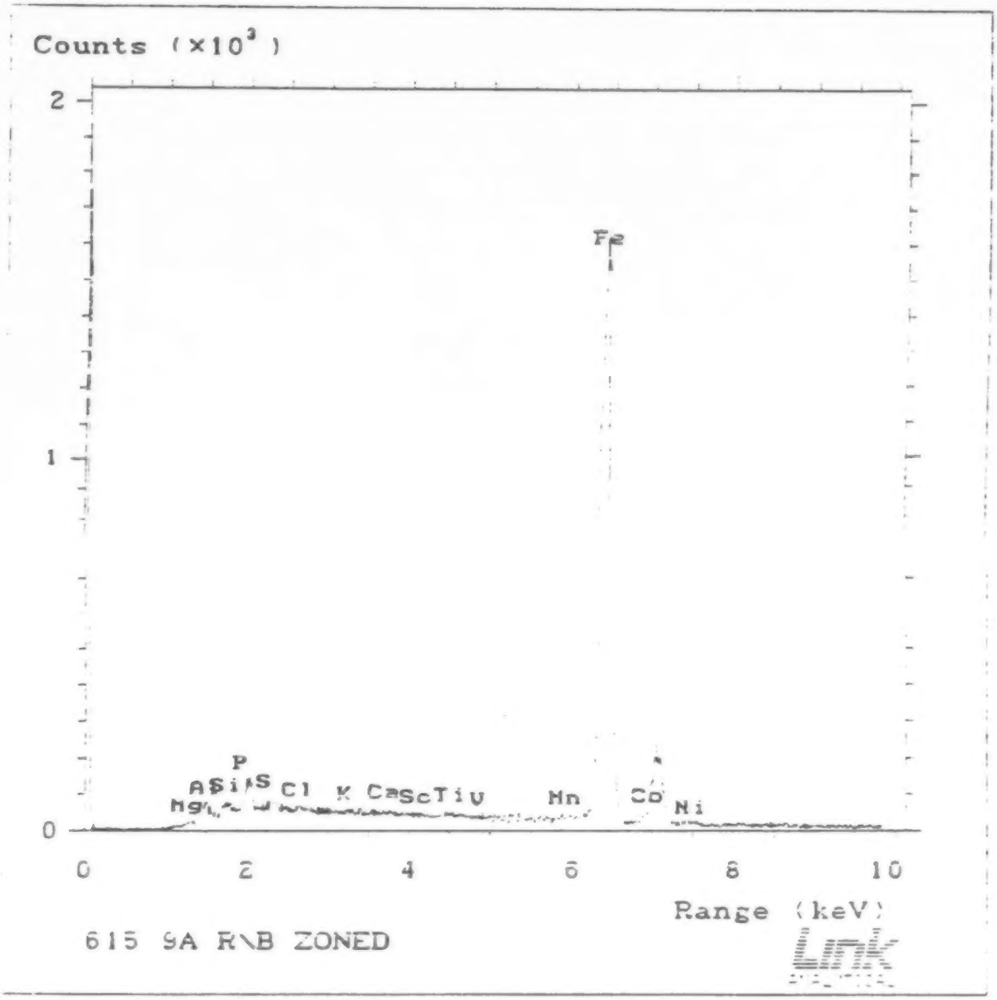
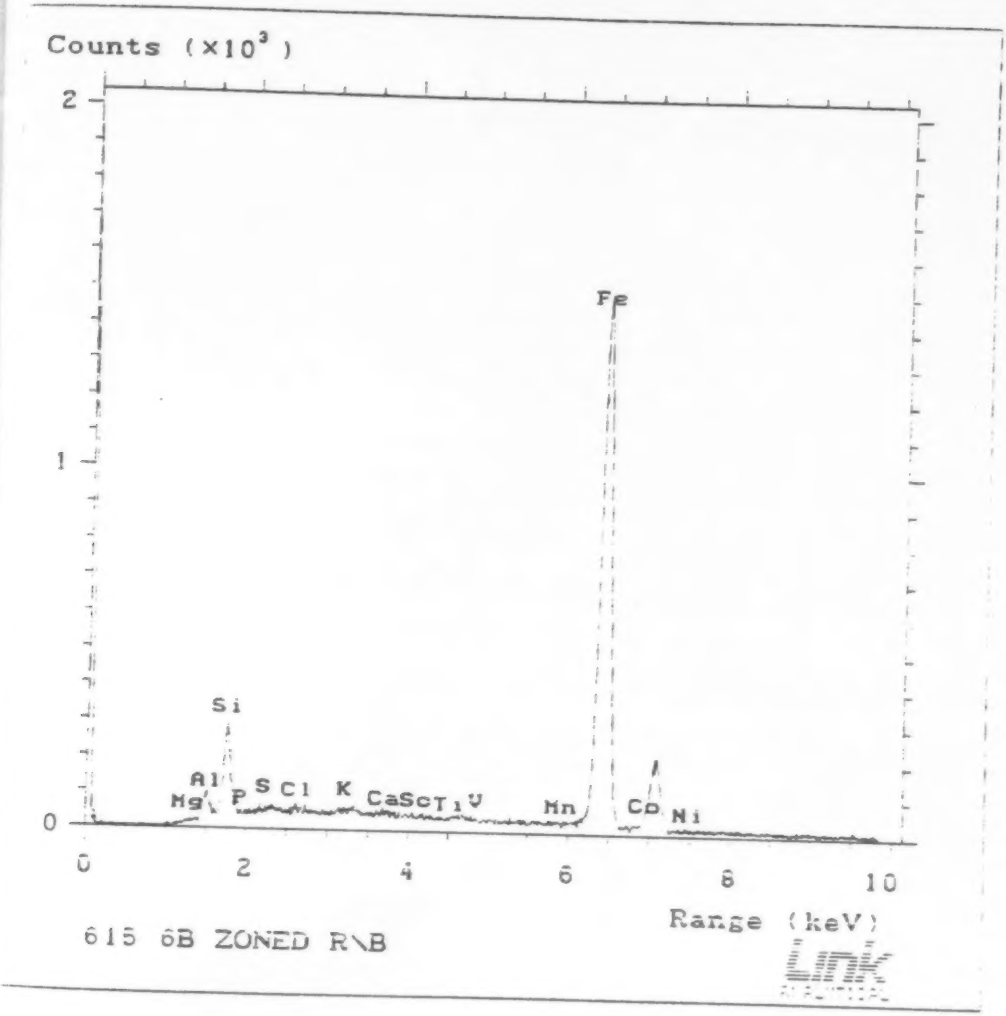
1
0
Fe
Mg
Al
Si
P
S
Cl
K
Ca
Sc
Ti
V
Mn
Co
Ni
0
2
4
6
8
10
Range (keV)
615 12A R\B ZONED
Link

PLOT IV.4


Counts (×10³)
2
1
0
Fe
P
Al Si S
Mg
Cl
K
Ca Sc Ti V
Mn
Co
Ni
0
2
4
6
8
10
Range (keV)
615 9A R\B ZONED
Link

PLOT IV.5


Counts (×10³)
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1
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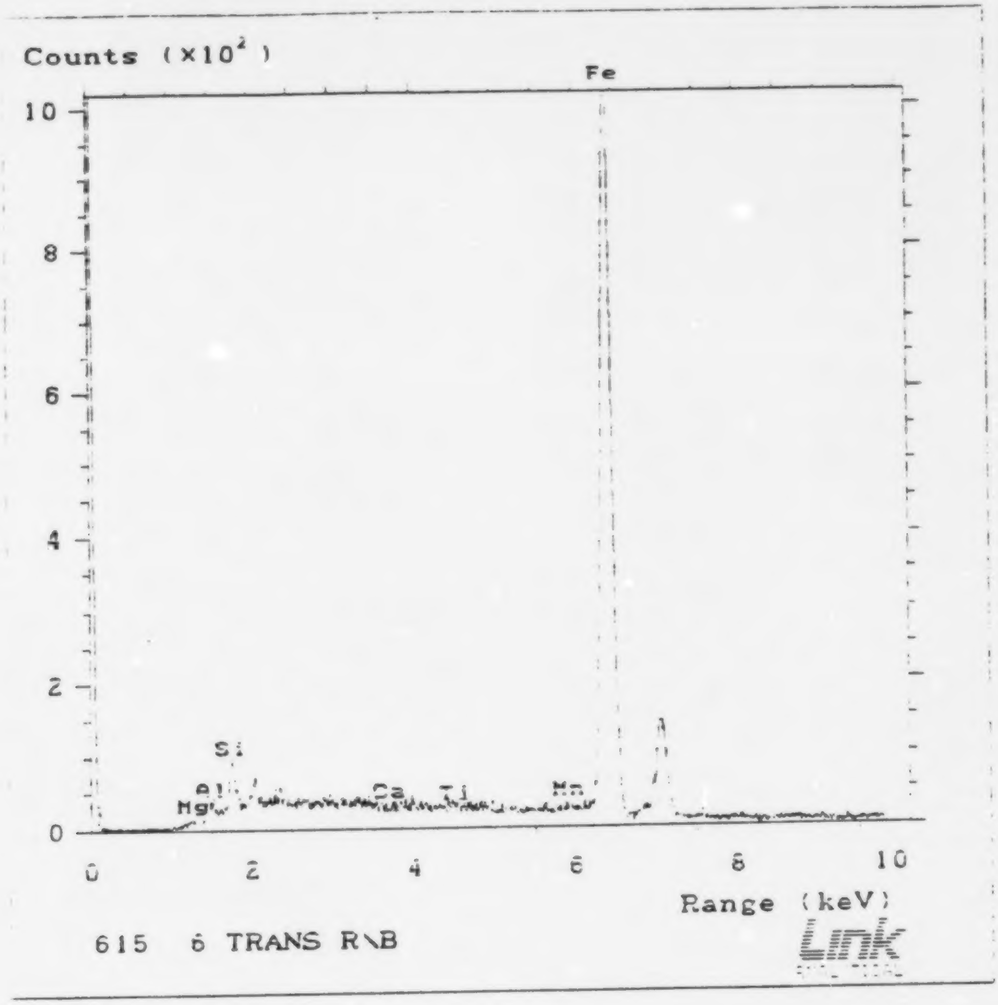
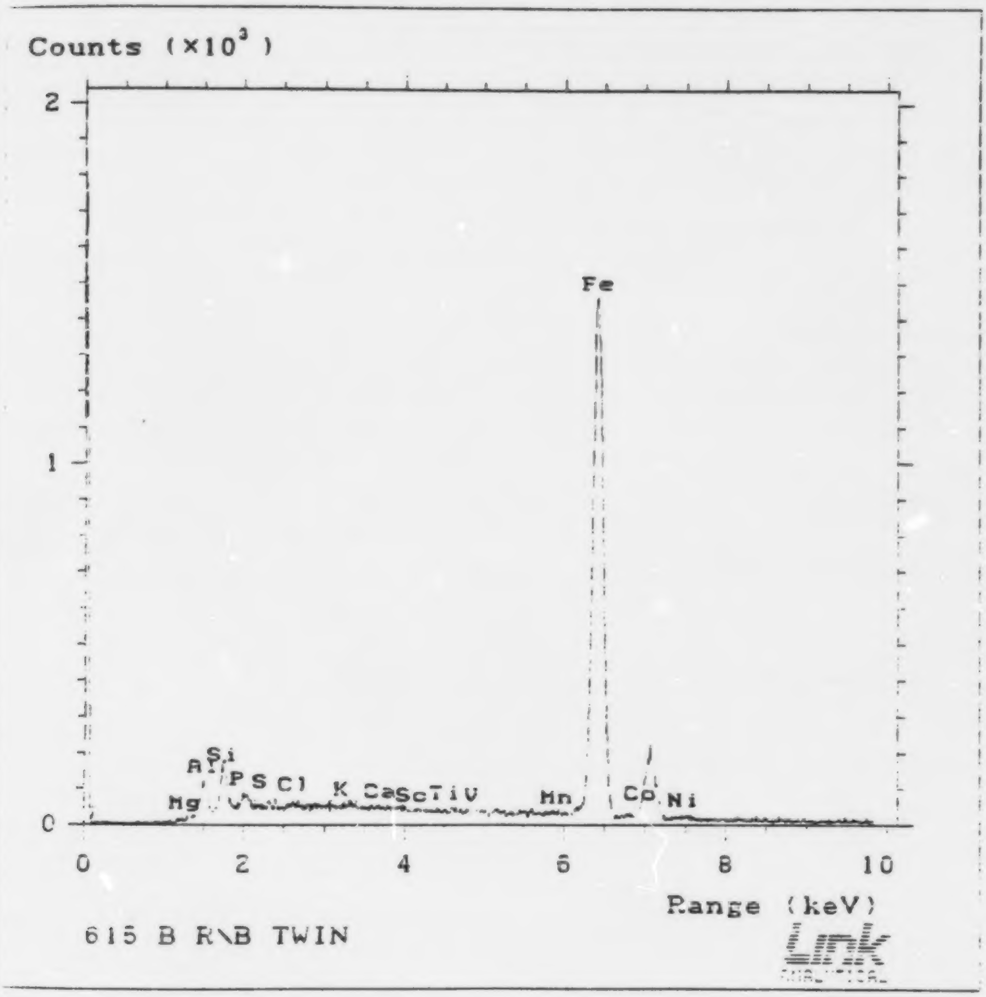
Si
Al
Mg
P
S
Cl
K
CaScTi
V
Mn
Fe
Co
Ni
0
2
4
6
8
10
Range (keV)
615 6B ZONED R\B
Link

PLOT IV.6


Counts (×10²)
Fe
10
8
6
4
2
0
Si
Al
Mg
Ca
Ti
Mn
0
2
4
6
8
10
Range (keV)
615 6 TRANS R\B
Link

PLOT IV.7


Counts (×10³)
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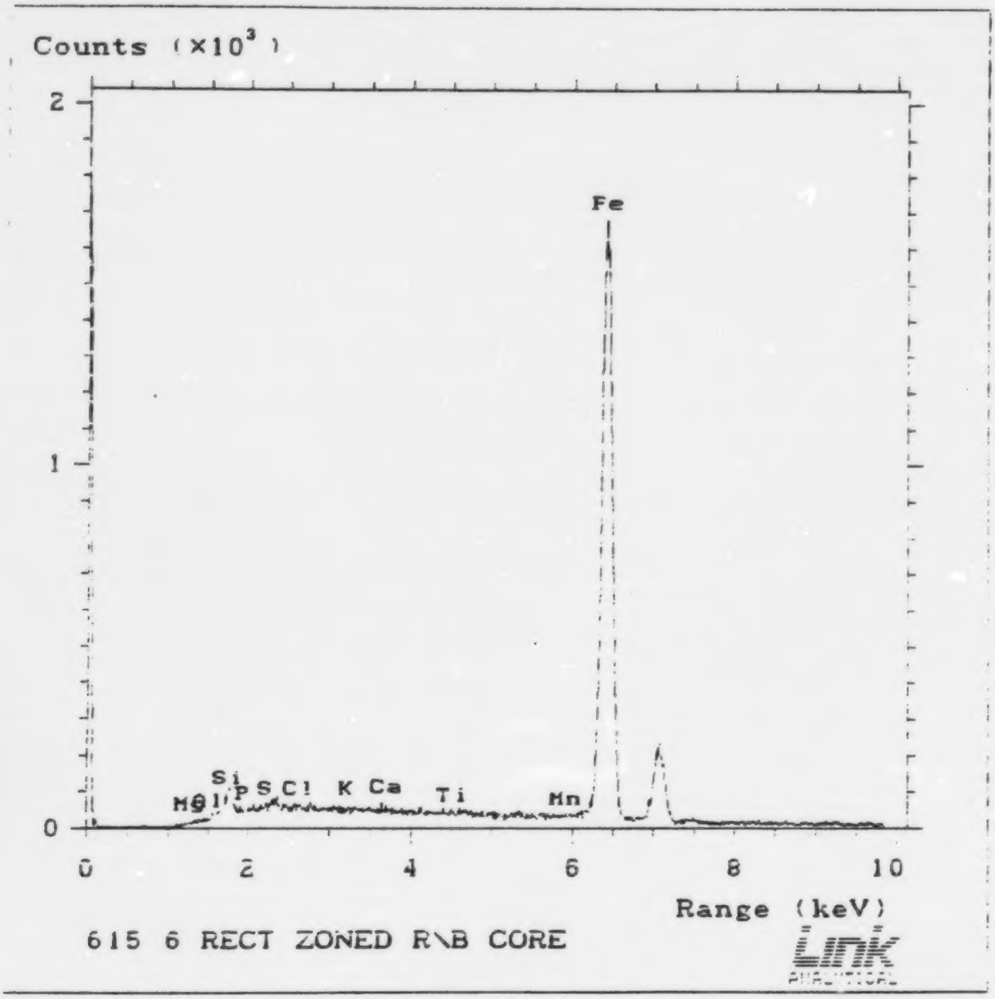
1
0
Fe
Mg
Al
Si
P
S
Cl
K
Ca
Sc
Ti
V
Mn
Co
Ni
0
2
4
6
8
10
Range (keV)
615 B R\B TWIN
Link
ANALYTICAL

PLOT IV.8


Counts (×10³)
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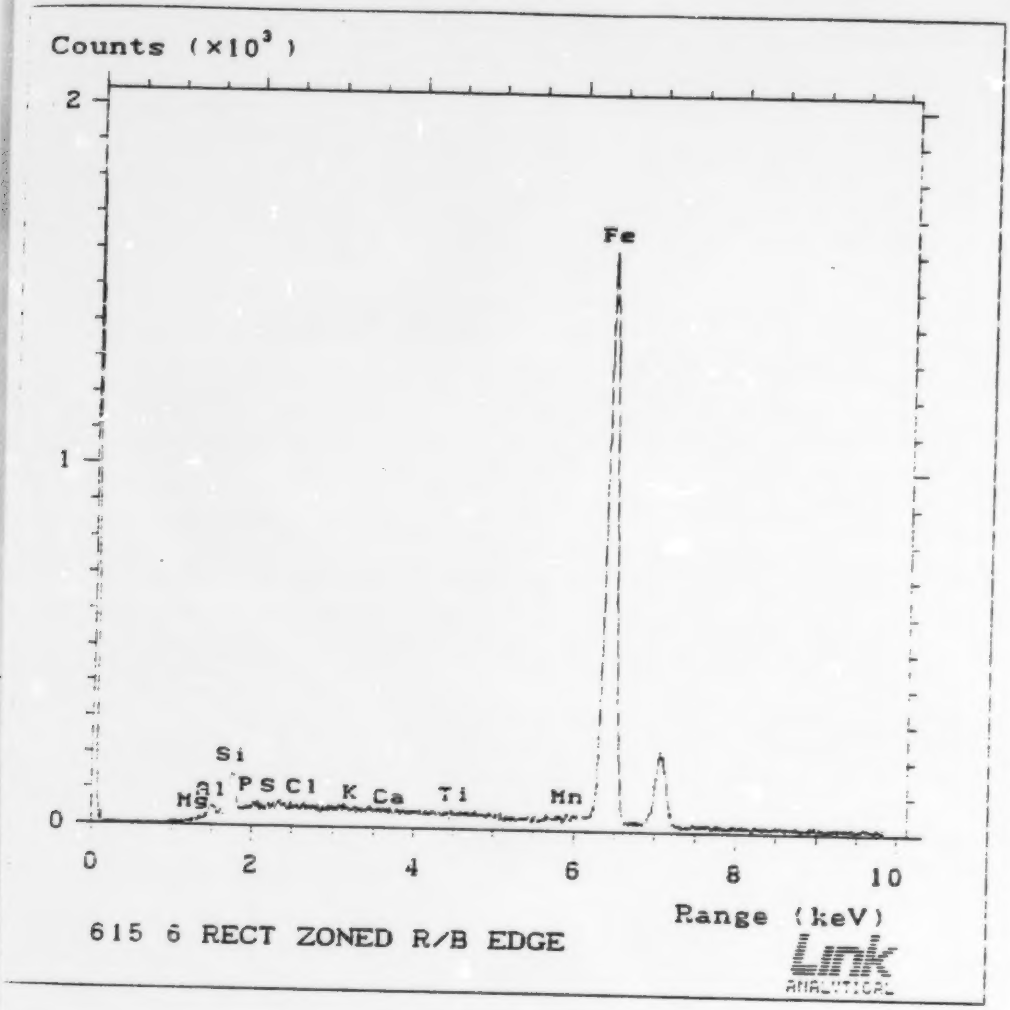
1
0
Fe
Mg
Si
Al
P
S
Cl
K
Ca
Ti
Mn
0
2
4
6
8
10
Range (keV)
615 6 RECT ZONED R\B CORE
Link

PLOT IV.9


Counts (×10³)
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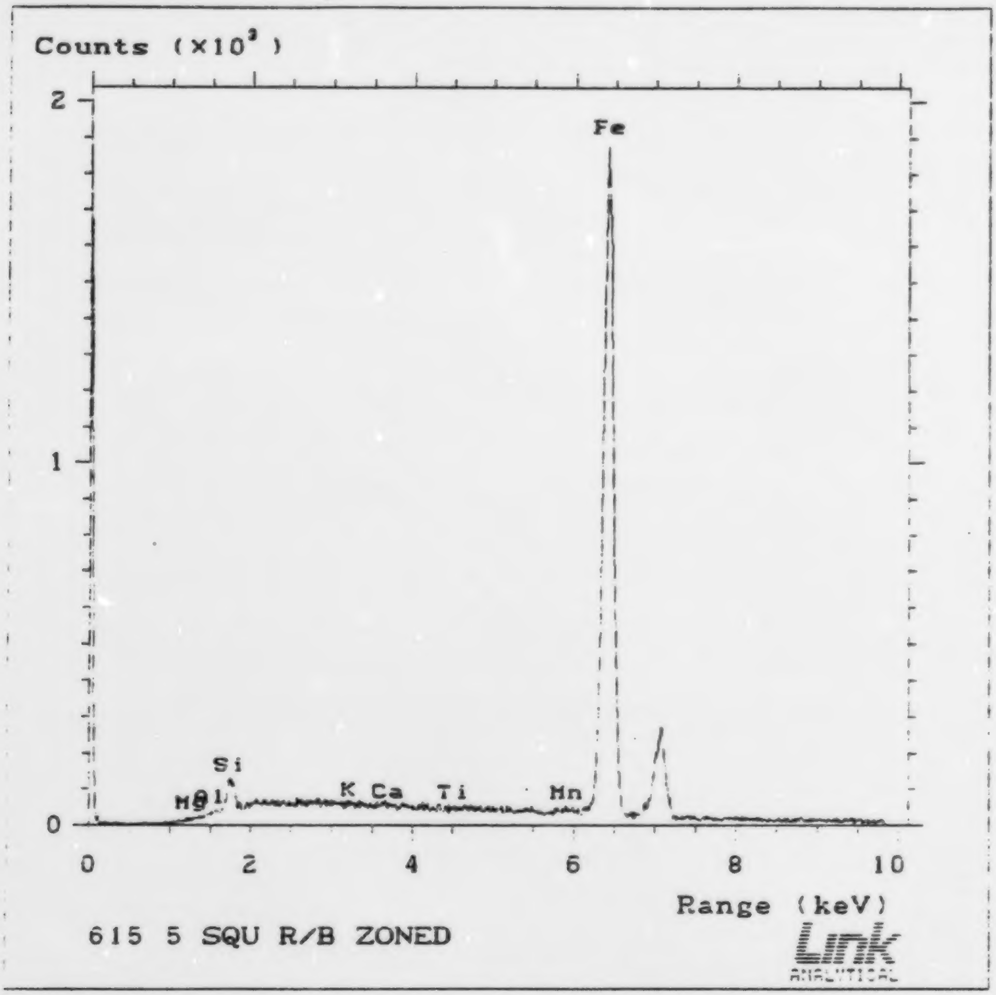
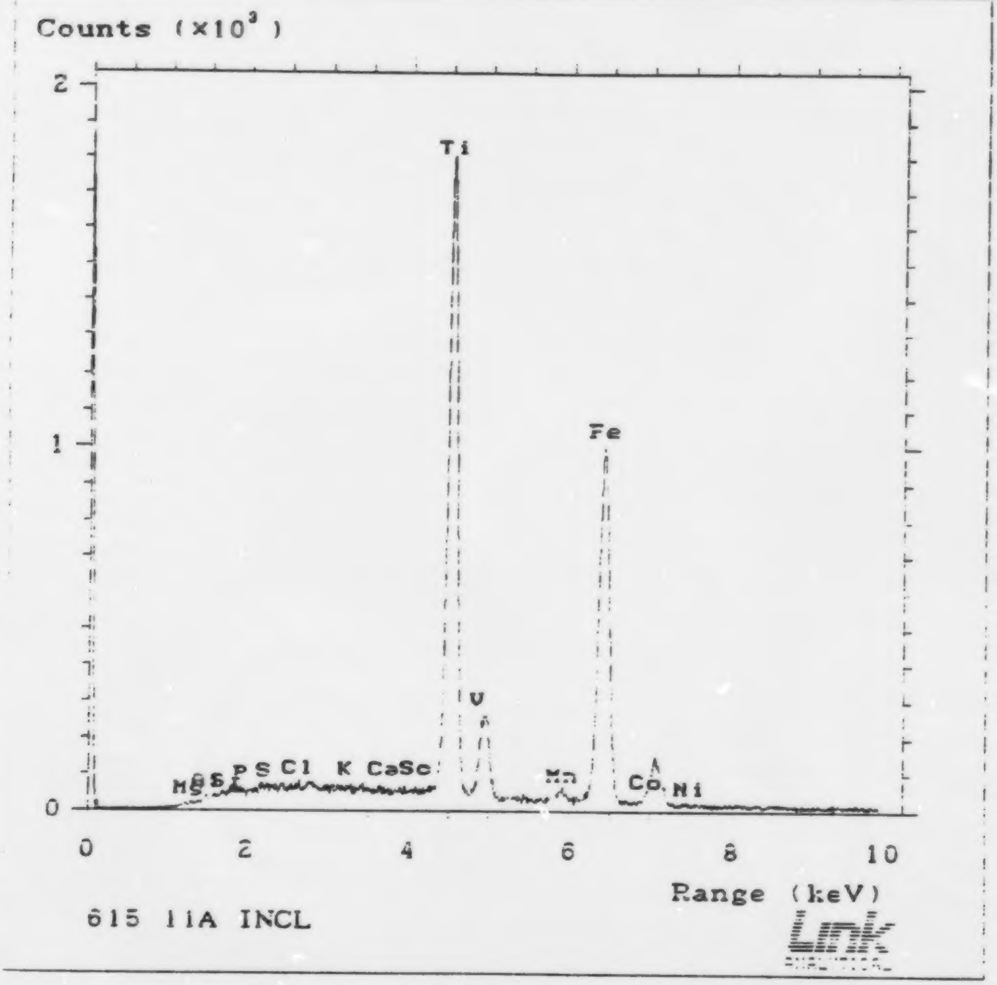
1
0
Fe
Si
Mg
Al
P
S
Cl
K
Ca
Ti
Mn
0
2
4
6
8
10
Range (keV)
615 6 RECT ZONED R/B EDGE
Link ANALYTICAL

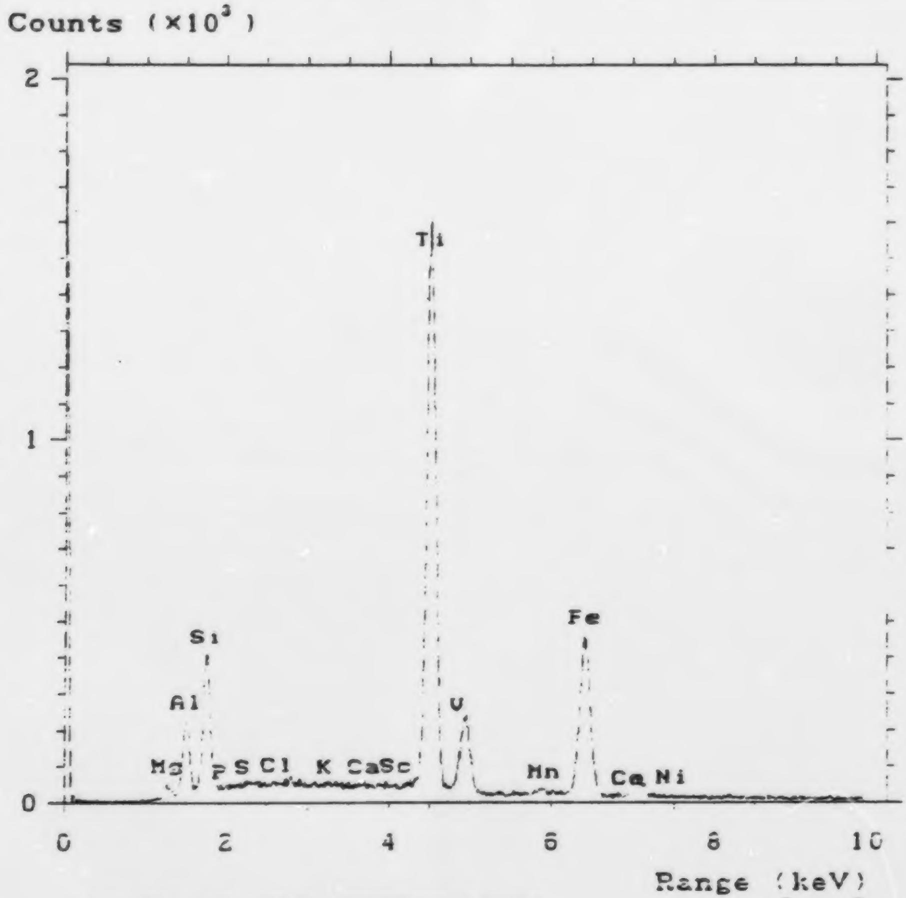
PLOT IV.10


Counts (×10³)
2
1
0
Fe
Si
Mg
Al
K
Ca
Ti
Mn
0
2
4
6
8
10
Range (keV)
615 5 SQU R/B ZONED
Link
ANALYTICAL

PLOT IV.11

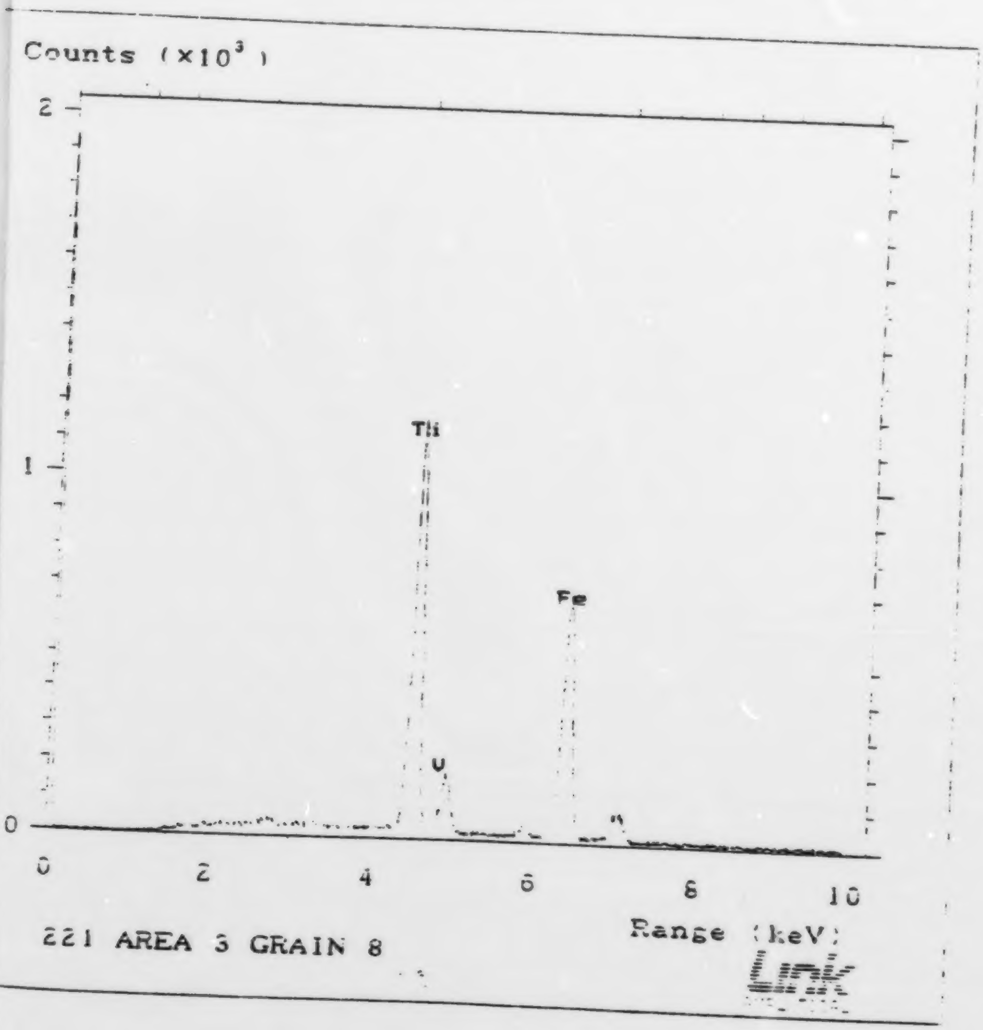

Counts (×10³)
2
1
0
Ti
V
Fe
Mg
Si
P
S
Cl
K
Ca
Sc
Mn
Co
Ni
0
2
4
6
8
10
Range (keV)
615 11A INCL
Link ANALYTICAL

PLOT IV.12

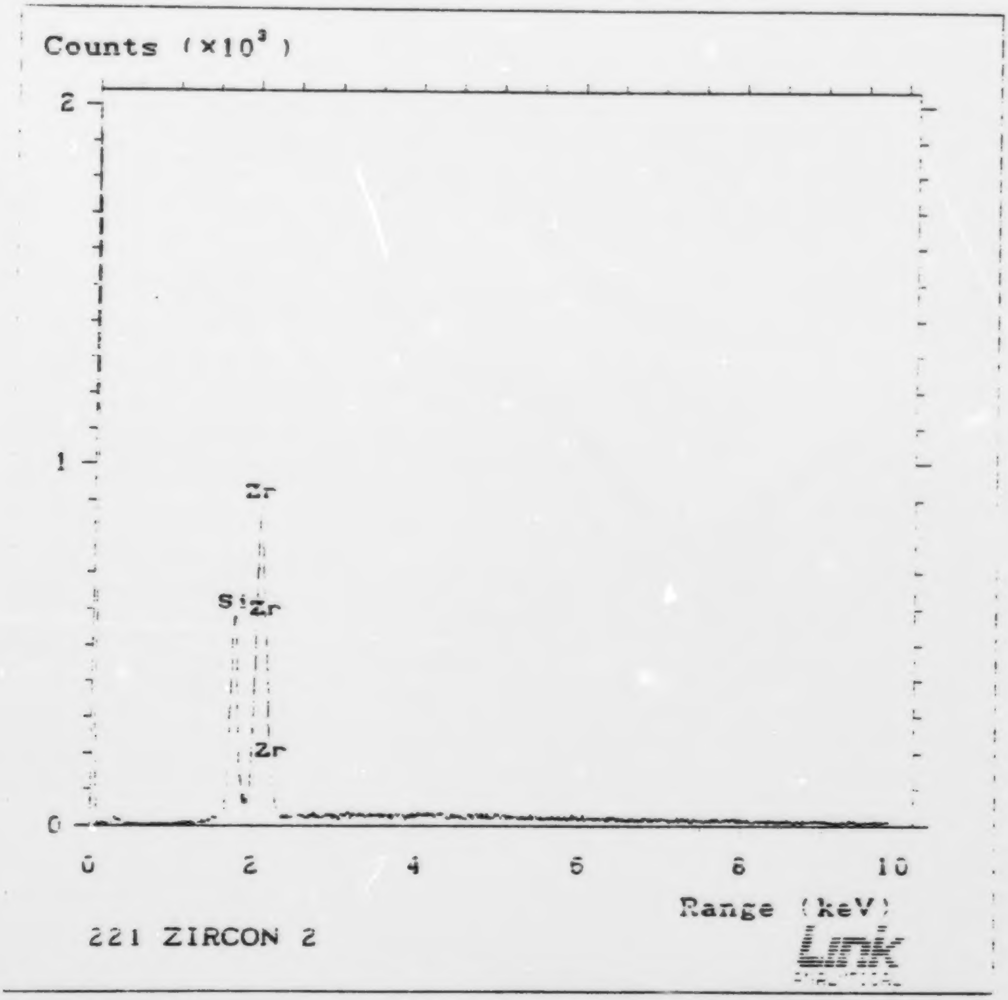


615 BY 12 SEE SKETCH V/TI

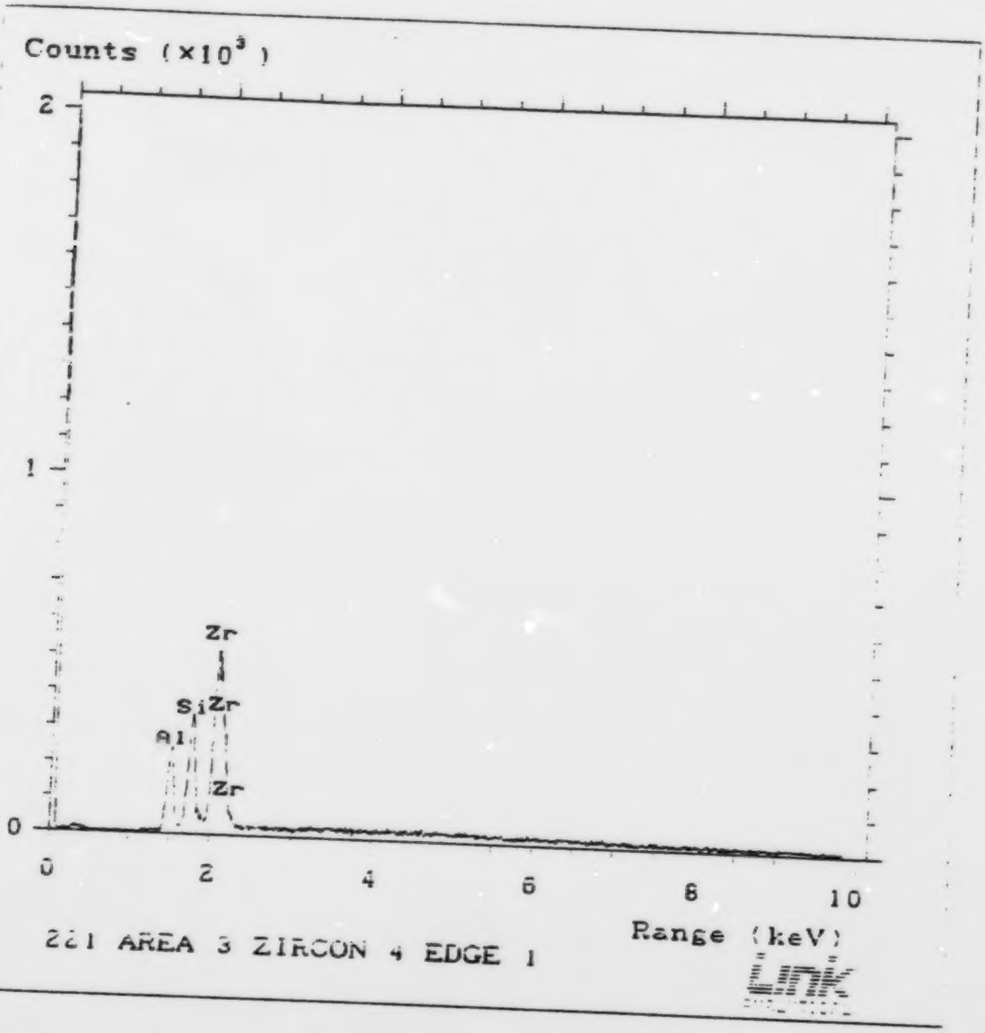
PLOT IV.13


Counts (×10³)
2
1
0
Th
U
Fe
0
2
4
6
8
10
Range (keV)
221 AREA 3 GRAIN 8
Link

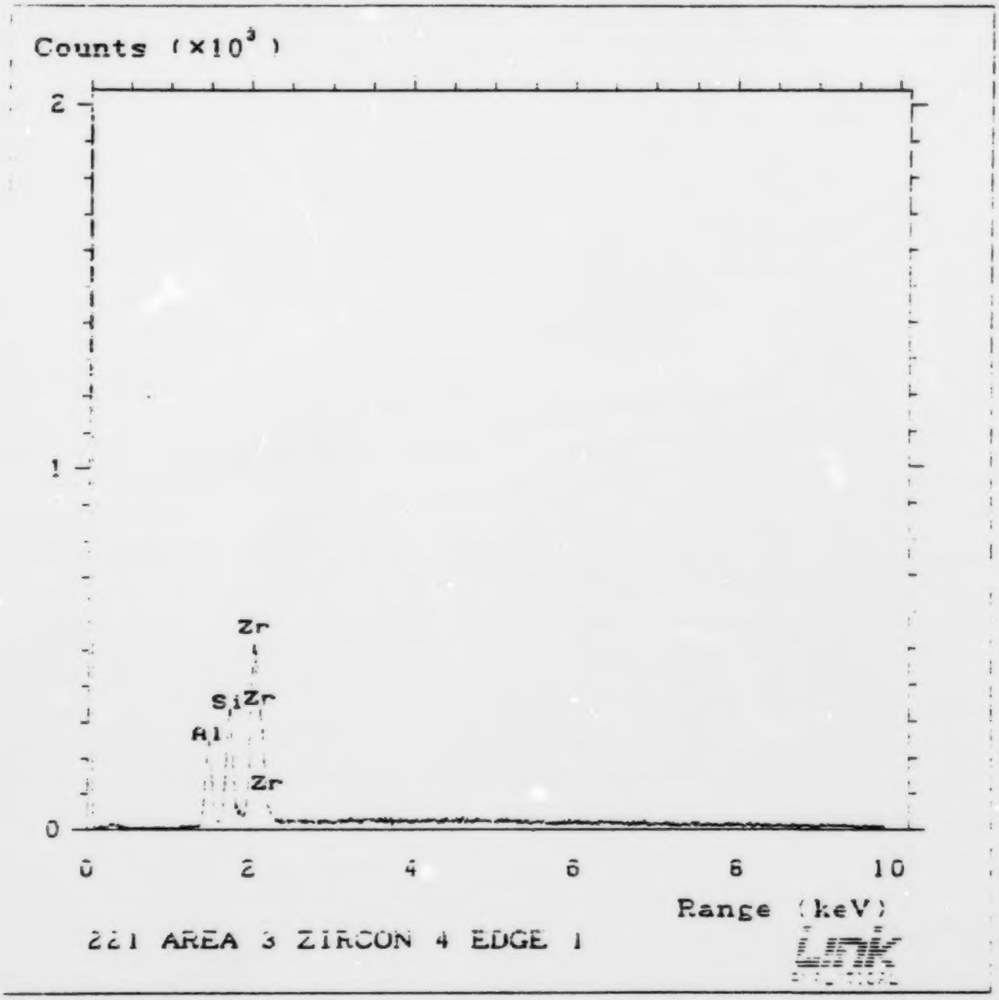
PLOT IV.14



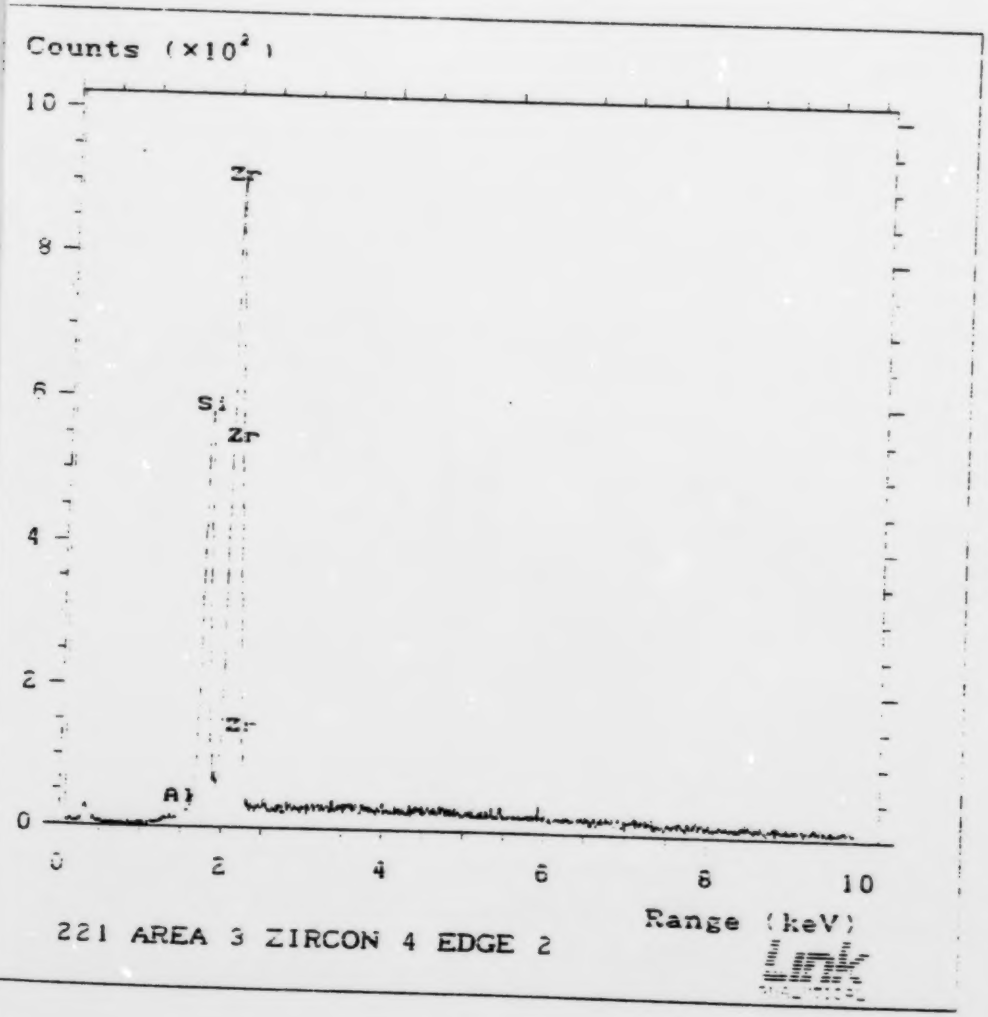
PLOT IV.15


Counts (×10³)
2
1
0
Zr
Si
Zr
Al
Zr
0
2
4
6
8
10
Range (keV)
221 AREA 3 ZIRCON 4 EDGE 1
LINK

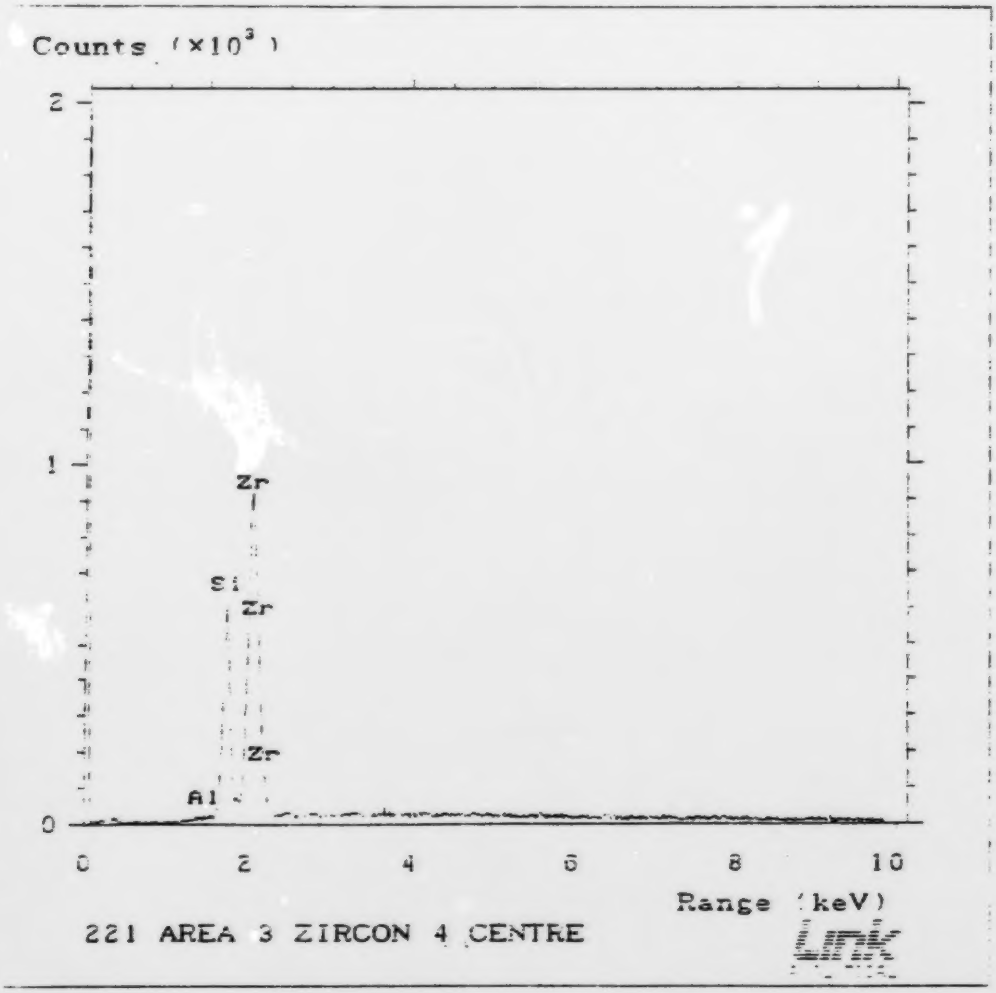
PLOT IV.15


Counts (×10³)
2
1
0
Zr
Si
Zr
Al
Zr
0
2
4
6
8
10
Range (keV)
221 AREA 3 ZIRCON 4 EDGE 1
Link

PLOT IV.16

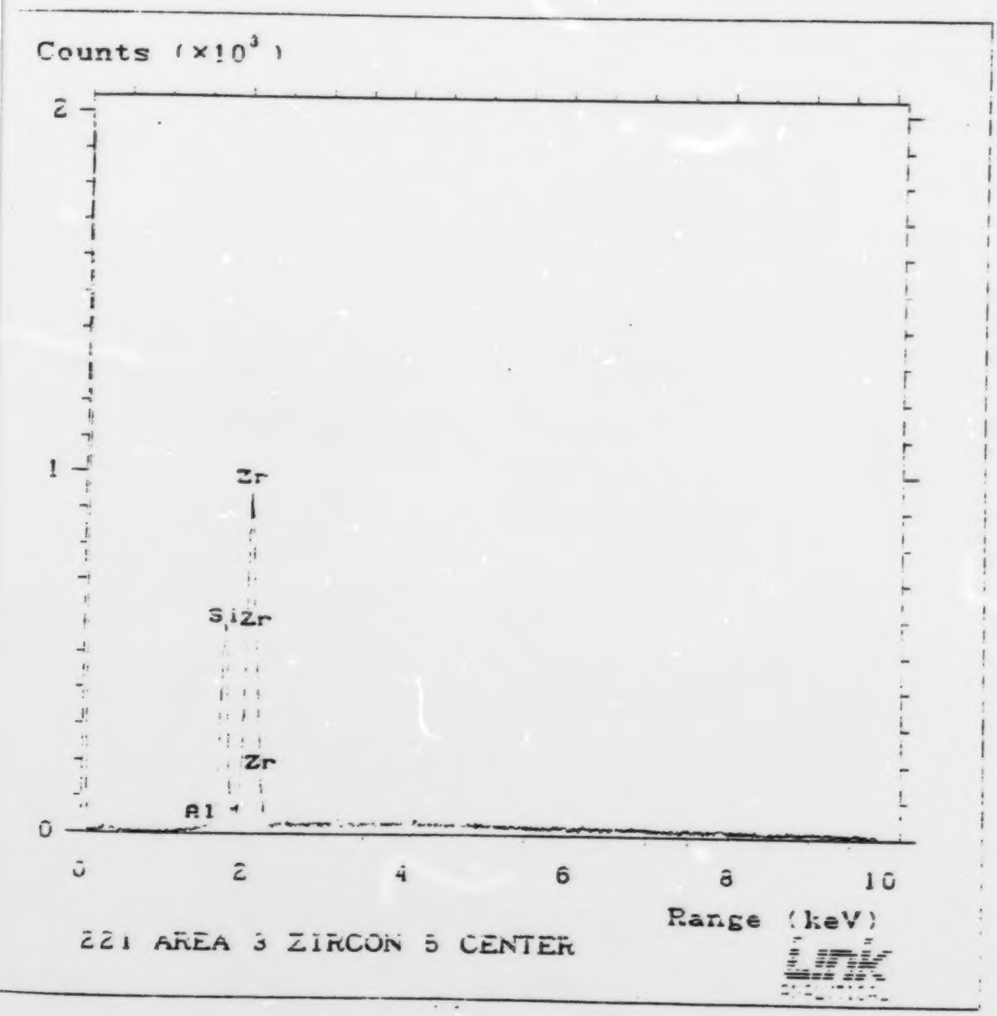

Counts (×10²)
10
8
6
4
2
0
Zr
Si
Zr
Zr
Al
0
2
4
6
8
10
Range (keV)
221 AREA 3 ZIRCON 4 EDGE 2
Link

PLOT IV.17

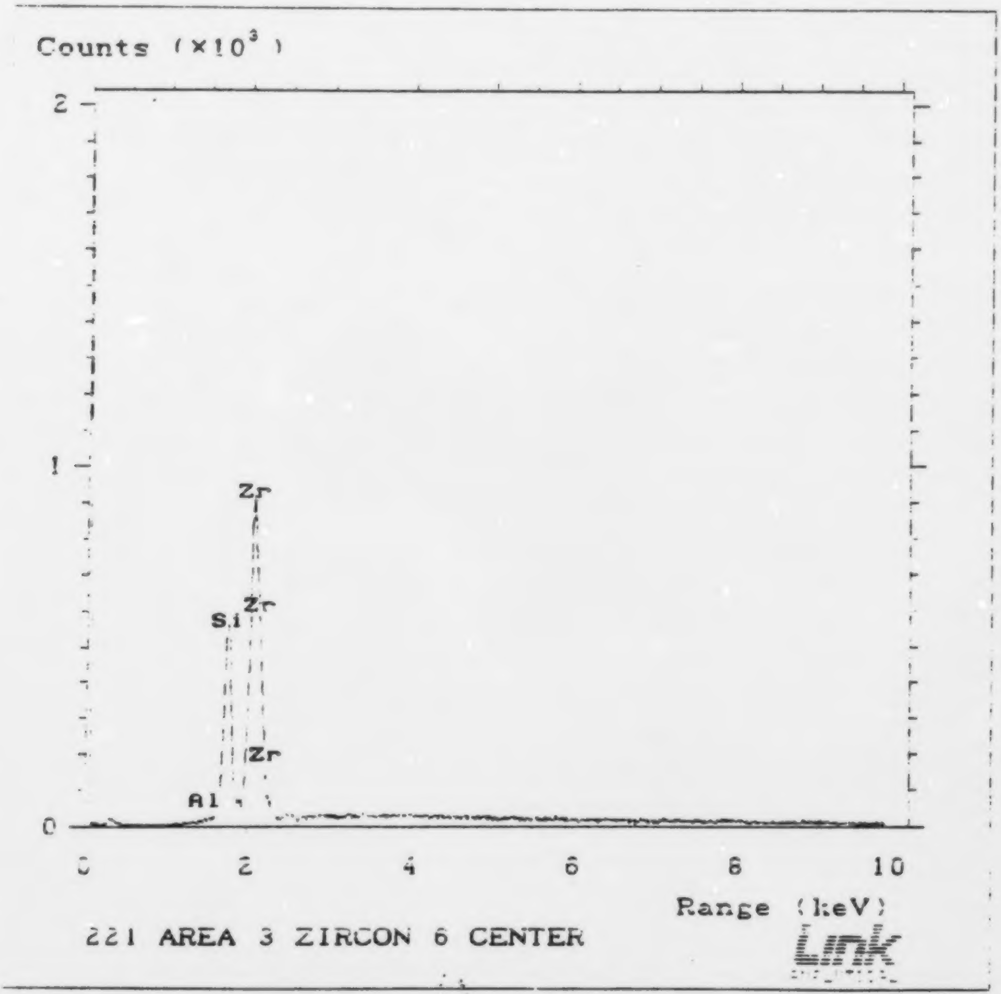


221 AREA 3 ZIRCON 4 CENTRE

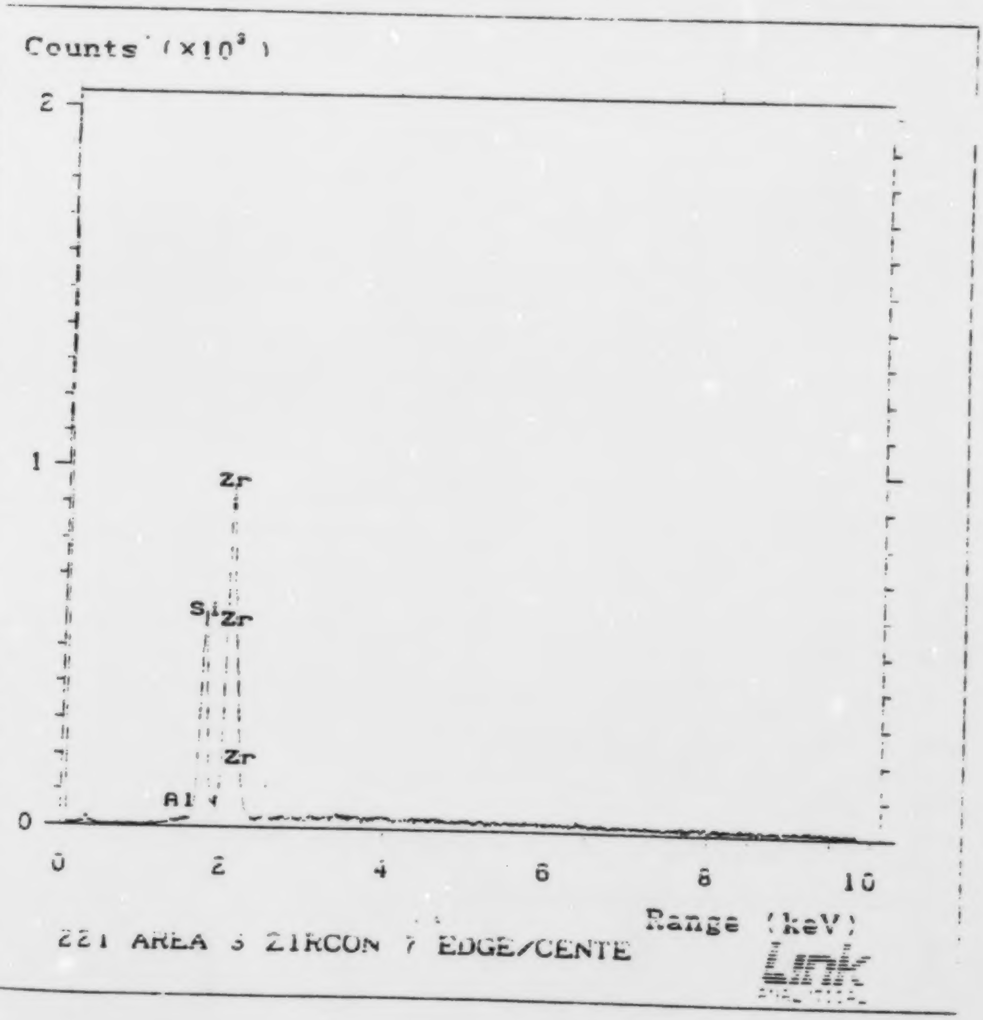
PLOT IV.18


Counts (×10³)
2
1
0
Zr
SiZr
Zr
Al
0
2
4
6
8
10
Range (keV)
221 AREA 3 ZIRCON 5 CENTER
Link

PLOT IV.19


Counts (×10³)
2
1
0
Zr
Zr
Si
Zr
Al
0
2
4
6
8
10
Range (keV)
221 AREA 3 ZIRCON 6 CENTER
Link

PLOT IV.20

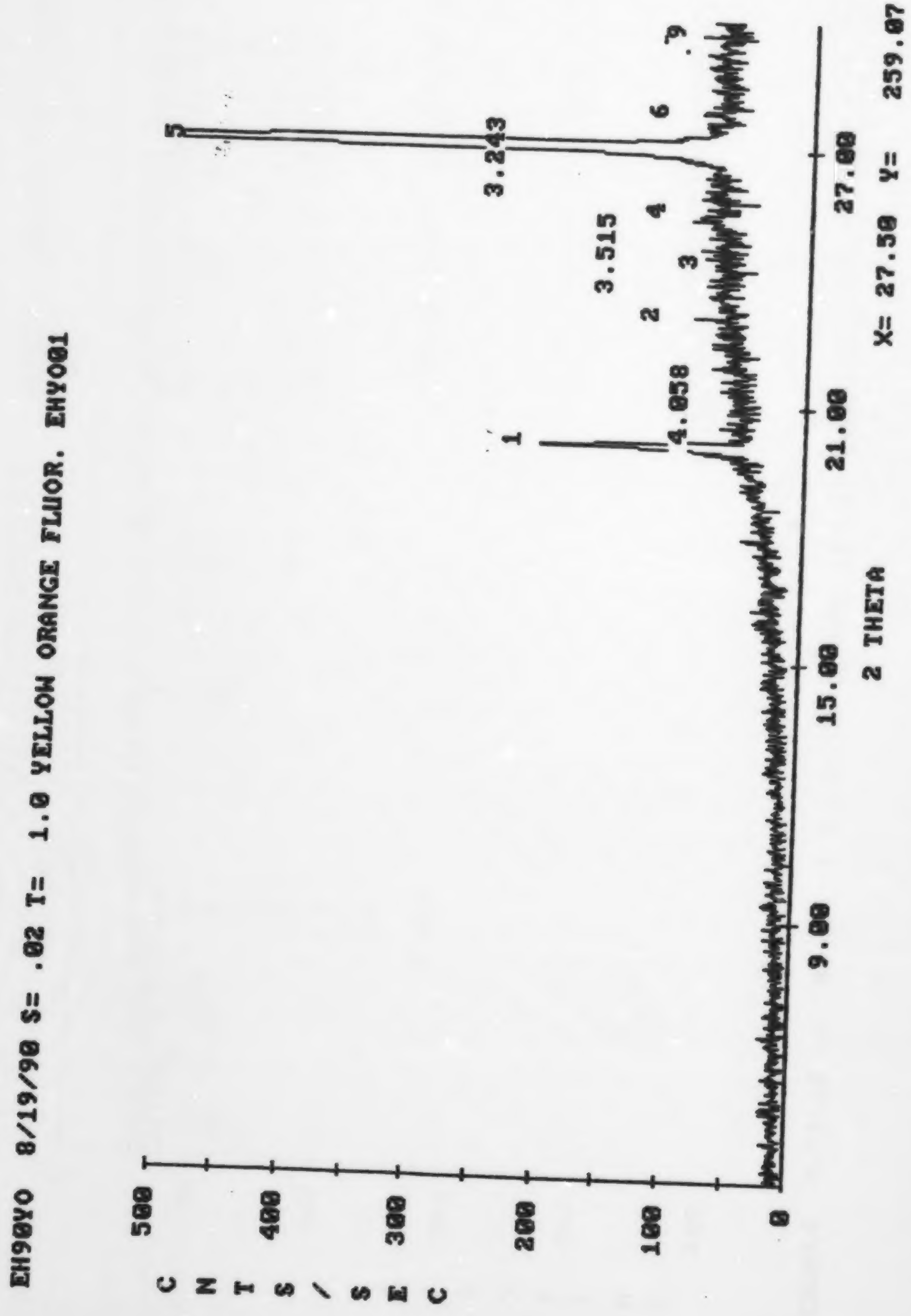

Counts (x10³)
2
1
0
Zr
Si
Zr
Zr
Al
0
2
4
6
8
10
Range (keV)
221 AREA 3 ZIRCON 7 EDGE/CENTE
Link

```
                         µPDSM Report                          14:27.8/19/90
```

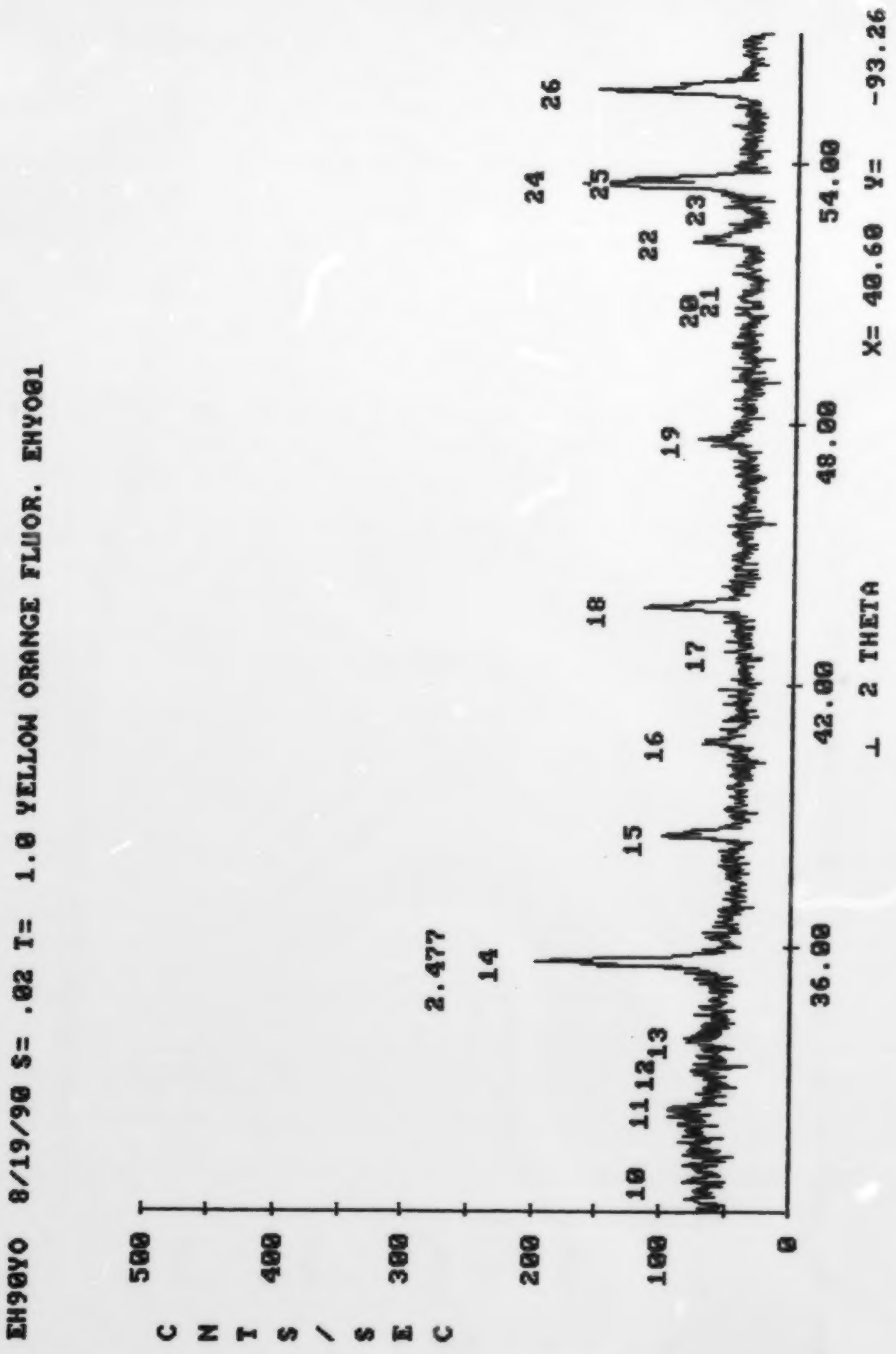
APPENDIX V

```
Input Pattern:

YELLOW ORANGE FLUORESCENT MINERAL
SAMPLE EH90Y001
      d         I        d        I        d        I        d        I        d        I
   4.4300     210     3.2070     88     2.4770     70     1.8020     47     1.6510     157
   4.0580      65     2.7680     93     2.3350    100     1.7940     46
   3.5150      75     2.6970     74     2.2170     69     1.7530     80
   3.3010    1064     2.6410     78     2.0670    116     1.7280     57
   3.2430      75     2.5180    197     1.9080     75     1.7130    169


Identified Phases:

 JCPDS#     SI    ML/X   At%   Identity . . .

 6-0266*   193    11/0    72  *Zirconium Silicate / Zircon = ZrSiO4
          Ierr:50,150     derr:2.0  Bground:46     dmax/min:4.469/1.645


Summary Report:

          Full  Resid    6-0266: 72%
   d        I     I       d       I
4.4300    210   None    4.434    346
4.0580     65     65
3.5150     75     75
3.3010   1064    298    3.302    769
3.2430     75     75
3.2070     88     88
2.7680     93     93
2.6970     74     74
2.6410     78   None    2.650     62
2.5180    197   None    2.518    346
2.4770     70     70
2.3350    100   None    2.336     77
2.2170     69   None    2.217     62
2.0670    116   None    2.066    154
1.9080     75   None    1.908    108
1.8020     47     47
1.7940     46     46
1.7530     80   None    1.751     92
1.7280     57     57
1.7130    169   None    1.712    308
1.6510    157   None    1.651    108
          * = Obscured      <..> = Missing     [..] = Previously Removed
```

APPENDIX V


EH90YO 8/19/90 S= .02 T= 1.0 YELLOW ORANGE FLUOR. EHYO01
CNTS/SEC
0
100
200
300
400
500
9.00
15.00
21.00
27.00
2 THETA
X= 27.50 Y= 259.07
1
4.058
2
3.515
3
4
5
3.243
6
9

APPENDIX V


EH90YO 8/19/90 S= .02 T= 1.0 YELLOW ORANGE FLUOR. EHYO01
CNTS/SEC
500
400
300
200
100
0
10
11
12
13
2.477
14
15
16
17
18
19
20
21
22
23
24
25
26
36.00
42.00
48.00
54.00
2 THETA
X= 40.60 Y= -93.26

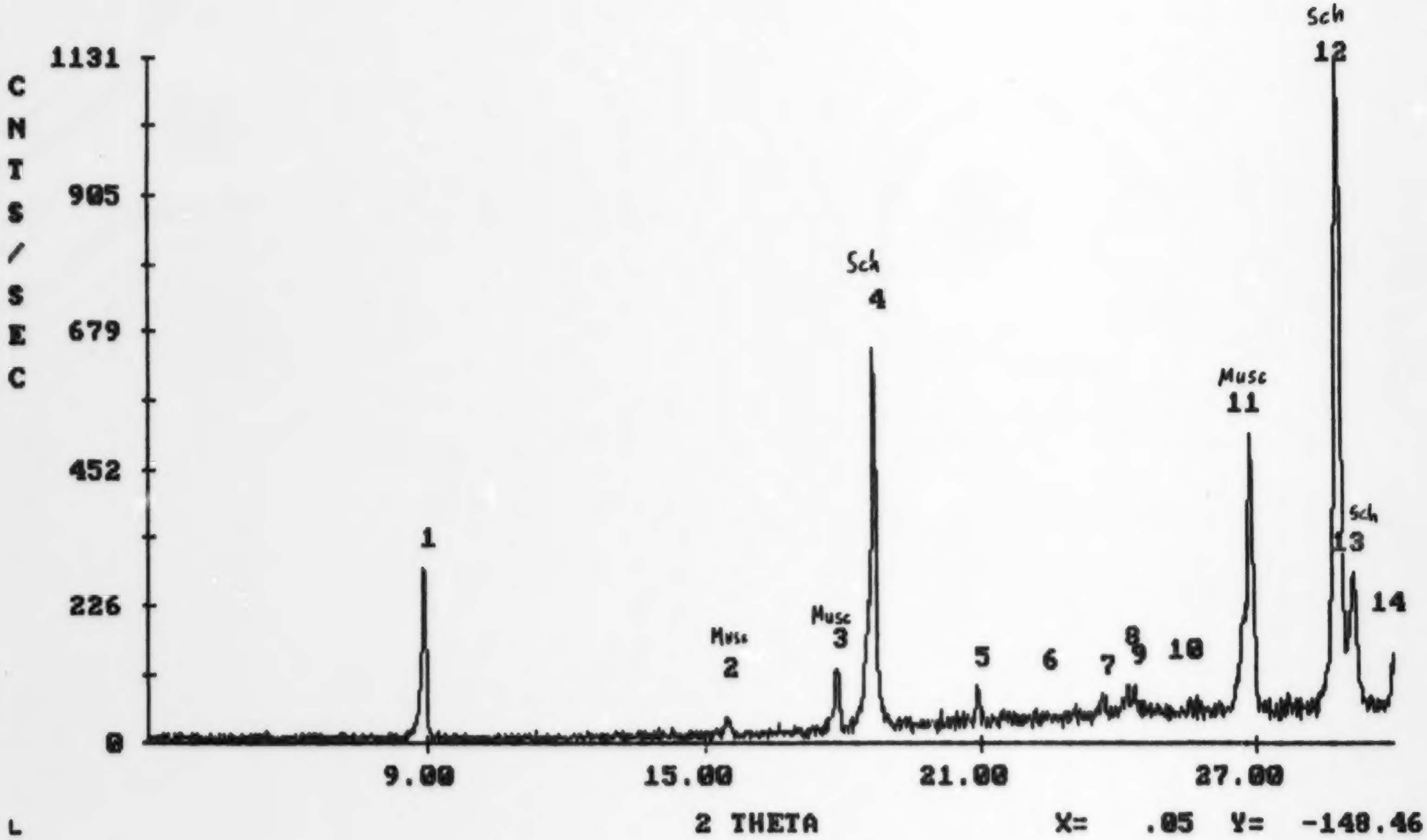
```
 3903   8-19-90         YELLOW ORANGE FLUOR. EHY001
START  ANGLE=     3.000   DELTA 2THETA=    .020   TIME=   1.0 TUBE=CU LAMDA= 1.542
SM= 0   BKGR= 0  0  0   KA2=0   TUBE=CU SCH= 9 SENS=5.00   CENTROID= 7 NTP= 5
  N     2THETA      DSPACE    (1/D**2)    HEIGHT        AREA          P          W2         W4
  1     20.043      4.4299      .0510      210.          25.         151.       .141       .121
  2     23.040      3.8600      .0671       90.          11.          17.       .164       .119
  3     24.281      3.6656      .0744       75.          11.          14.       .164       .148
  4     25.419      3.5039      .0815       95.          17.          28.       .211       .179
  5     27.007      3.3014      .0918     1064.         141.        1029.       .164       .132
  6     27.822      3.2065      .0973       88.          11.          20.       .141       .124
  7     29.200      3.0582      .1069       86.          11.          18.       .141       .126
  8     29.459      3.0320      .1088       77.          12.          18.       .164       .153
  9     29.658      3.0121      .1102       91.           8.          18.       .094       .084
 10     30.683      2.9138      .1178       80.          10.          18.       .141       .124
 11     32.339      2.7682      .1305       93.          12.          26.       .141       .132
 12     33.217      2.6970      .1375       74.           8.          15.       .117       .107
 13     33.939      2.6413      .1433       78.           8.          15.       .117       .108
 14     35.662      2.5175      .1578      197.          28.         123.       .164       .142
 15     38.560      2.3347      .1835      100.          10.          29.       .117       .102
 16     40.703      2.2166      .2035       69.          11.          34.       .188       .164
 17     42.781      2.1136      .2238       53.           5.          14.       .117       .100
 18     43.800      2.0668      .2341      116.          12.          46.       .117       .100
 19     47.657      1.9081      .2747       75.           6.          13.       .094       .080
 20     50.656      1.8020      .3080       47.           8.          20.       .211       .178
 21     50.900      1.7939      .3107       46.           7.          16.       .164       .145
 22     52.183      1.7528      .3255       80.          16.          47.       .235       .195
 23     53.001      1.7277      .3350       57.           7.          13.       .164       .117
 24     53.500      1.7127      .3409      169.          17.          75.       .117       .100
 25     53.622      1.7091      .3423      133.          11.          28.       .094       .084
 26     55.662      1.6512      .3668      157.          16.          67.       .117       .099
 27.    57.459      1.6038      .3888       44.           6.          16.       .141       .128
 28     59.760      1.5474      .4176       67.           5.          16.       .094       .082
```

```
                       µPDSM Report                     17:31,8/11/90


Input Pattern:

BLUE WHITE FLUORESCENT MINERAL IN ULTRA-VIOLET LIGHT
SAMPLE EH90BW01
     d       I         d       I         d       I         d       I         d       I
  9.9130   290      3.4850    70      2.8380   323      2.2550    61      1.7160    50
  5.7170    40      3.3190   515      2.6230   237      2.0860    80      1.6880   121
  4.9720   121      3.1060  1131      2.4870    98      1.9940   268      1.6840   100
  4.7590   653      3.0690   283      2.4580    68      1.9270   179      1.6330    65
  4.2500    92      2.9820   147      2.3960    61      1.8570   126
  3.7630    79      2.9510   129      2.3860    63      1.8150    51
  3.6810    94      2.8760    78      2.3270    49      1.7740    59
  3.6570    93      2.8630   114      2.2990   148      1.7270    74


Identified Phases:

 JCPDS#     SI    ML/X  At%  Identity . . .

 7-0210I   261    14/0  103  *Calcium Tungsten Oxide / Scheelite = CaWO4
          Ierr:50,150   derr:2.0  Bground:40    dmax/min:10.11/1.627

 6-0263I   109    13/*   28  *Potassium Aluminum Silicate Hydroxide / Muscovite-
                             2M1 = KAl2(Si3Al)O10(OH,F)2
          Ierr:50,150   derr:2.0  Bground:40    dmax/min:10.11/1.627


Summary Report:

          Full  Resid   7-0210:103%     6-0263: 28%
   d       I      I       d       I       d       I
9.9130   290   None                     9.95    302
5.7170    40     40
4.9720   121   None                     4.97     95
4.7590   653   None     4.76    639
                                       <4.47     64>
4.2500    92     92
                                       <3.88     44>
3.7630    79     79
                                       <3.73     57>
3.6810    94     94
3.6570    93     93
3.4850    70   None                     3.48     64
3.3190   515   None                     3.34     79
  "     "     "                         3.32    318
                                       <3.19     95>
3.1060  1131   None     3.10   1162    [3.12      6]
3.0690   283   None    3.072    348
2.9820   147   None                    2.987    111
2.9510   129    129
2.8760    78     78
2.8630   114   None                    2.859     79
2.8380   323    161    2.844    163
                                      <2.789     64>
2.6230   237   None    2.622    290
                                      <2.596     51>
```

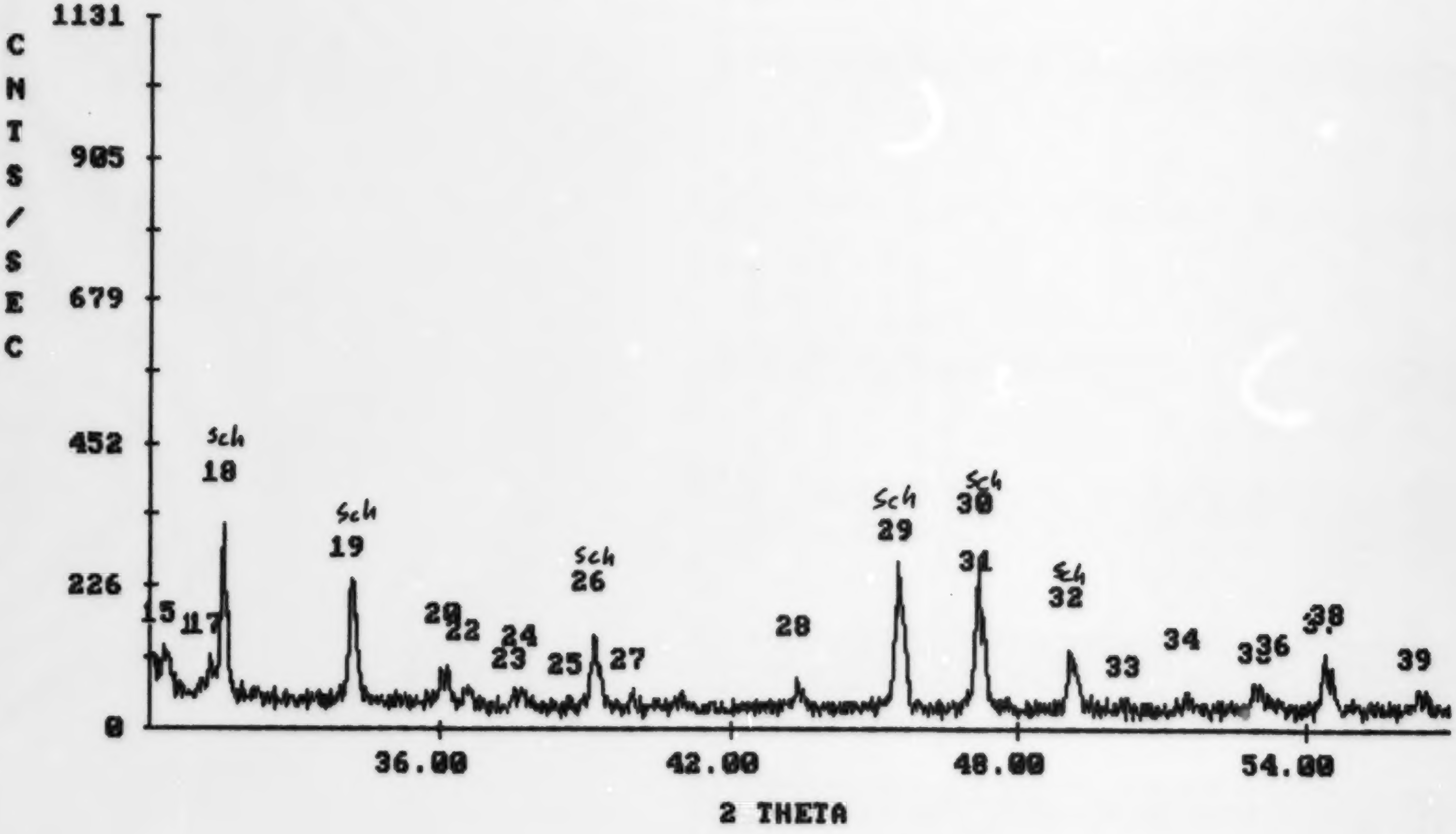
2.4580	68	None			2.465	25
" "	"				2.450	25
2.3960	61	None			2.398	32
2.3860	63	None			2.384	79
2.3270	49	49				
2.2990	148	None	2.296	232		
2.2550	61	None	2.256	46	[2.254	32]
					<2.149	51>
					<2.132	64>
2.0860	80	None	2.0864	70		
1.9940	268	None	1.9951	163	1.993	143
1.9270	179	None	1.9278	348		
1.8570	126	None	1.8538	139		
1.8150	51	51				
1.7740	59	59				
1.7270	74	None	1.7278	70	[1.731	25]
1.7160	50	50				
1.6880	121	None	1.6882	186		
1.6840	100	100				
					<1.646	79>
1.6330	65	None	1.6332	116	[1.631	19]

* = Obscured   <..> = Missing   [..] = Previously Removed

EH90BW 8/11/90 S= .02 T= 1.0 BLUE-WHITE FLUOR. EH90BW01



EH90BW 8/11/90 S= .02 T= 1.0 BLUE-WHITE FLUOR. EH90BW01



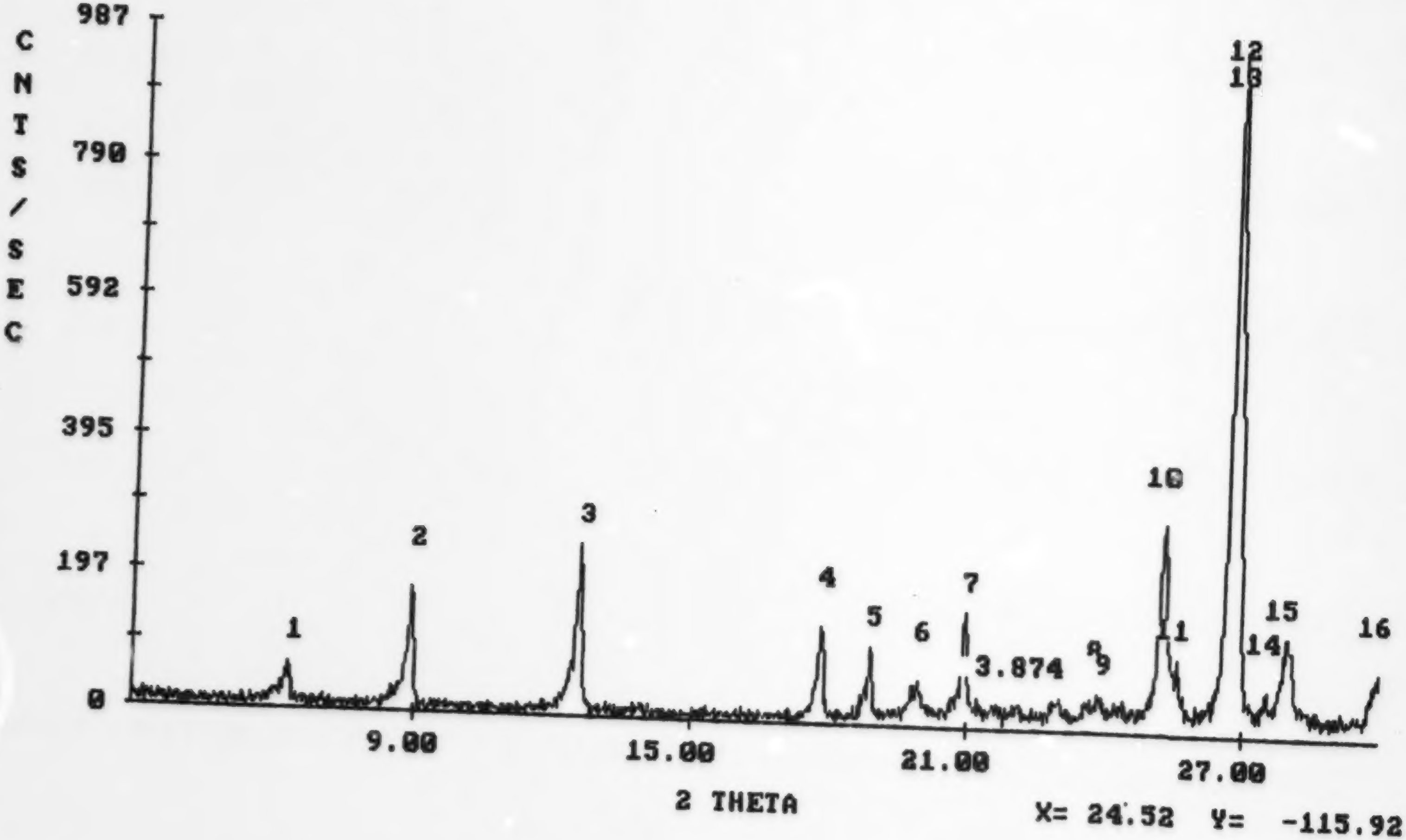
```
 3903  8-11-90        BLUE-WHITE FLUOR. EH90BW01
START ANGLE=    3.000  DELTA 2THETA=   .020  TIME=  1.0 TUBE=CU LAMDA= 1.542
SM= 0   BKGR= 0 0 0  KA2=0  TUBE=CU SCH= 9 SENS=5.00  CENTROID= 7 NTP= 5

   N    2THETA    DSPACE   (1/D**2)  HEIGHT      AREA        P       W2      W4

   1     8.921    9.9127    .0102     290.        28.      219.     .117    .095
   2    15.498    5.7173    .0306      40.         6.       23.     .164    .139
   3    17.839    4.9719    .0405     121.        15.       97.     .141    .120
   4    18.644    4.7590    .0442     653.        70.      512.     .141    .107
   5    20.900    4.2502    .0554      92.         9.       45.     .117    .096
~~ 6    22.420    3.9652    .0636      51.         9.       20.     .211    .181~~
   7    23.642    3.7632    .0706      79.        11.       22.     .164    .134
   8    24.178    3.6808    .0738      94.         8.       18.     .094    .087
   9    24.337    3.6572    .0748      93.         9.       23.     .117    .096
  10    25.559    3.4850    .0823      70.         9.       17.     .141    .124
  11    26.861    3.3190    .0908     515.        58.      335.     .141    .113
  12    28.744    3.1057    .1037    1131.       150.      987.     .164    .133
  13    29.098    3.0688    .1062     283.        41.      179.     .164    .145
  14    29.965    2.9819    .1125     147.        17.       52.     .141    .112
  15    30.282    2.9513    .1148     129.        26.       58.     .235    .201
  16    31.098    2.8758    .1209      78.        10.       13.     .141    .127
  17    31.242    2.8629    .1220     114.        12.       34.     .117    .104
  18    31.518    2.8384    .1241     323.        39.      236.     .164    .120
  19    34.181    2.6232    .1453     237.        38.      204.     .188    .161
  20    36.121    2.4866    .1617      95.        10.       22.     .117    .105
  21    36.121    2.4866    .1617      98.         8.       17.     .094    .085
  22    36.560    2.4577    .1656      68.        13.       41.     .211    .192
  23    37.538    2.3959    .1742      61.         7.       16.     .141    .120
  24    37.700    2.3860    .1757      63.         6.       14.     .117    .103
  25    38.697    2.3268    .1847      49.         5.       15.     .141    .110
  26    39.183    2.2990    .1892     148.        20.       79.     .164    .134
  27    39.980    2.2550    .1967      61.         6.       18.     .117    .095
  28    43.381    2.0858    .2299      80.         8.       25.     .117    .101
  29    45.500    1.9935    .2516     268.        31.      136.     .141    .116
  30    47.157    1.9272    .2692     275.        26.      123.     .117    .096
  31    47.174    1.9266    .2694     179.        11.       19.     .070    .060
  32    49.065    1.8566    .2901     126.        16.       58.     .141    .125
  33    50.265    1.8151    .3035      51.         5.       19.     .117    .105
  34    51.500    1.7744    .3176      59.         8.       18.     .164    .135
  35    53.039    1.7265    .3355      74.         8.       21.     .117    .105
  36    53.401    1.7156    .3397      50.         7.       14.     .164    .140
  37    54.363    1.6875    .3511     121.        12.       53.     .117    .102
  38    54.500    1.6836    .3528     100.         9.       22.     .094    .085
  39    56.337    1.6330    .3750      65.         6.       20.     .094    .092
x 40    57.846    1.5940    .3936     165.        27.      111.     .188    .165
x 41    59.498    1.5536    .4143      89.        12.       45.     .164    .137
```

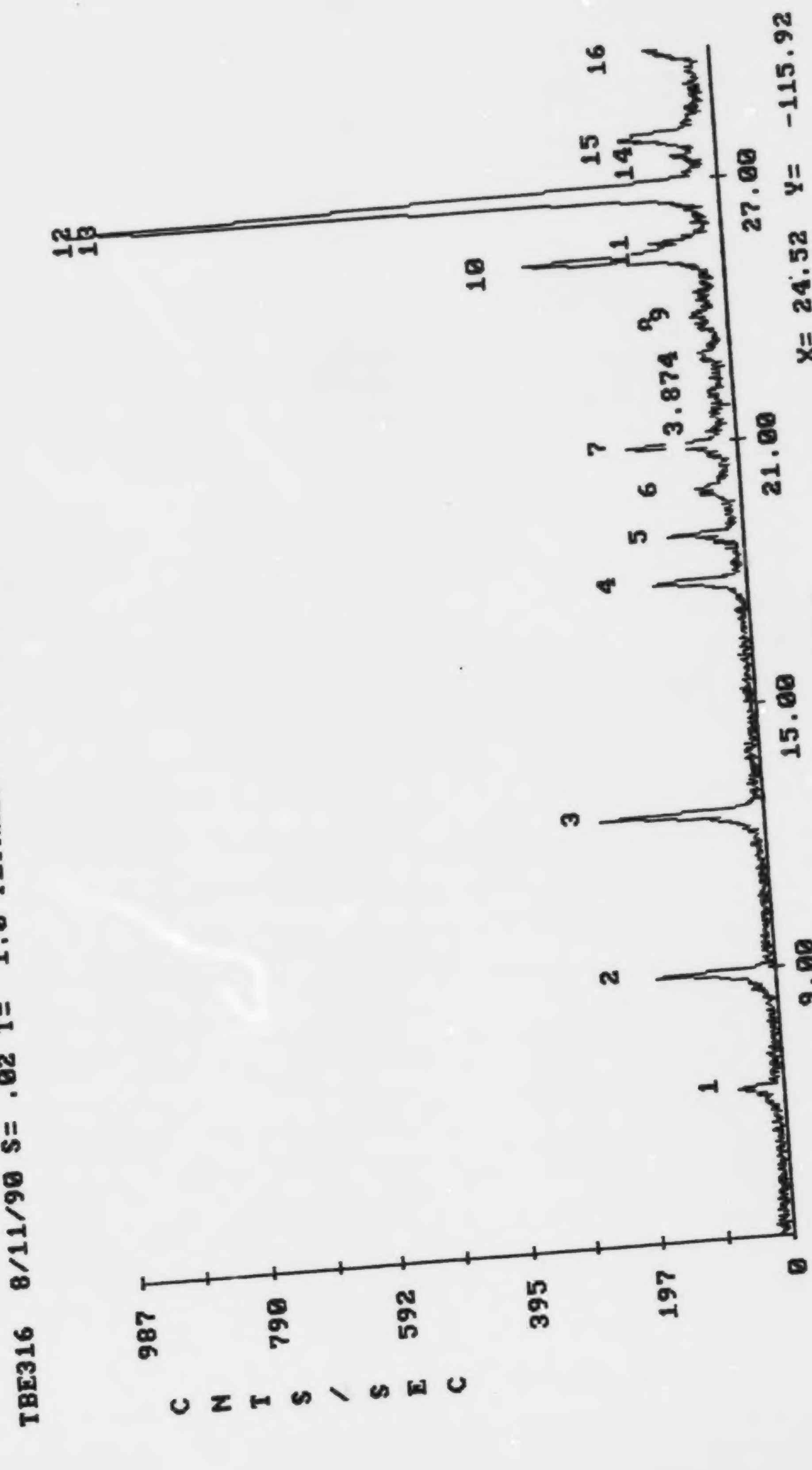
```
                       µPDSM Report                          17:22,8/11/90


Input Pattern:

TETRABROMOETHANE FLOAT MATERIAL AFTER BROMOFORM SEPARATION
SAMPLE 316
     d          I          d          I          d          I          d          I          d          I
   13.991      67       3.8740      25       3.1950      145      2.4920      86       1.9990     272
   9.9160     177       3.7610      47       2.9810       96      2.4520     111       1.9760      25
   7.0390     249       3.7320      55       2.8590       98      2.3910      50       1.9480      35
   4.9810     138       3.5280     305       2.8260       87      2.3760      50       1.9150      31
   4.7030     112       3.4850     110       2.7900       68      2.2790      85       1.8830      25
   4.4570      65       3.3360     987       2.5920       50      2.2330      30       1.8170     144
   4.2460     167       3.2430      65       2.5620      123      2.1280     108       1.6590      63


Identified Phases:

 JCPDS#     ST    ML/X   At%  Identity . . .

 6-0263I  277    24/6    42  *Potassium Aluminum Silicate Hydroxide / Muscovite-
                              2M1 = KAl2(Si3Al)O10(OH,F)2
         Ierr:50,150    derr:2.0  Bground:25    dmax/min:14.39/1.653

33-1161*   83     5/1    71  *Silicon Oxide / Quartz, low = SiO2
         Ierr:50,150    derr:2.0  Bground:25    dmax/min:14.39/1.653

29-0701I   88     6/0    37  *Iron Magnesium Aluminum Silicate Hydroxide /
                              Clinochlore-IIb, ferroan = (Mg,Fe)6(Si,Al)4O10(OH)8
         Ierr:50,150    derr:2.0  Bground:25    dmax/min:14.39/1.653


Summary Report:

        Full   Resid    6-0263: 42%    33-1161: 71%    29-0701: 37%
   d      I      I        d       I      d        I       d       I
13.991    67   None                                     14.10    127
9.9160   177   None      9.95    392
7.0390   249   None                                      7.07    364
4.9810   138   None      4.97    124
4.7030   112   None                                      4.71    109
4.4570    65   None      4.47     83
4.2460   167   None                    4.257    154
3.8740    25   None      3.88     58
3.7610    47     47
3.7320    55   None      3.73     74
3.5280   305   None                                      3.54    219
3.4850   110   None      3.48     83
3.3360   987   None      3.34    103*    3.342    702
 "   "     "             3.32    413*
3.2430    65     65
3.1950   145   None      3.19    124
2.9810    96   None     2.987    144
2.8590    98   None     2.859    103
2.8260    87   None                                     2.828     55
2.7900  · 68   None     2.789     83
2.5920    50   None     2.596     66                    [2.597     33]
2.5620   123   None     2.566    227                    [2.558     22]
```

2.4920	86	None	2.491	58				
			<2.465	33>				
2.4520	111	None	2.450	33	2.457	56	[2.453	22]
2.3910	50	None	2.398	41			[2.387	22]
2.3760	50	None	2.384	103			" "	"
2.2790	85	None			2.282	56		
			<2.254	41>				
2.2330	30	None	2.236	17	[2.237	28]		
			<2.208	33>				
			<2.149	66>				
2.1280	108	None	2.132	83	[2.127	42]		
1.9990	272	None	1.993	186			[2.006	33]
1.9760	25	None	1.972	41	[1.9792	28]		
1.9480	35	None	1.951	25				
" "	"		1.941	17				
1.9150	31	31						
1.8830	25	None					1.886	18
1.8170	144	None	1.822	17*	1.8179	98	[1.823	11]
			<1.731	33>	<1.6719	28>		
1.6590	63	None	1.662	50	[1.6591	14]	[1.661	11]

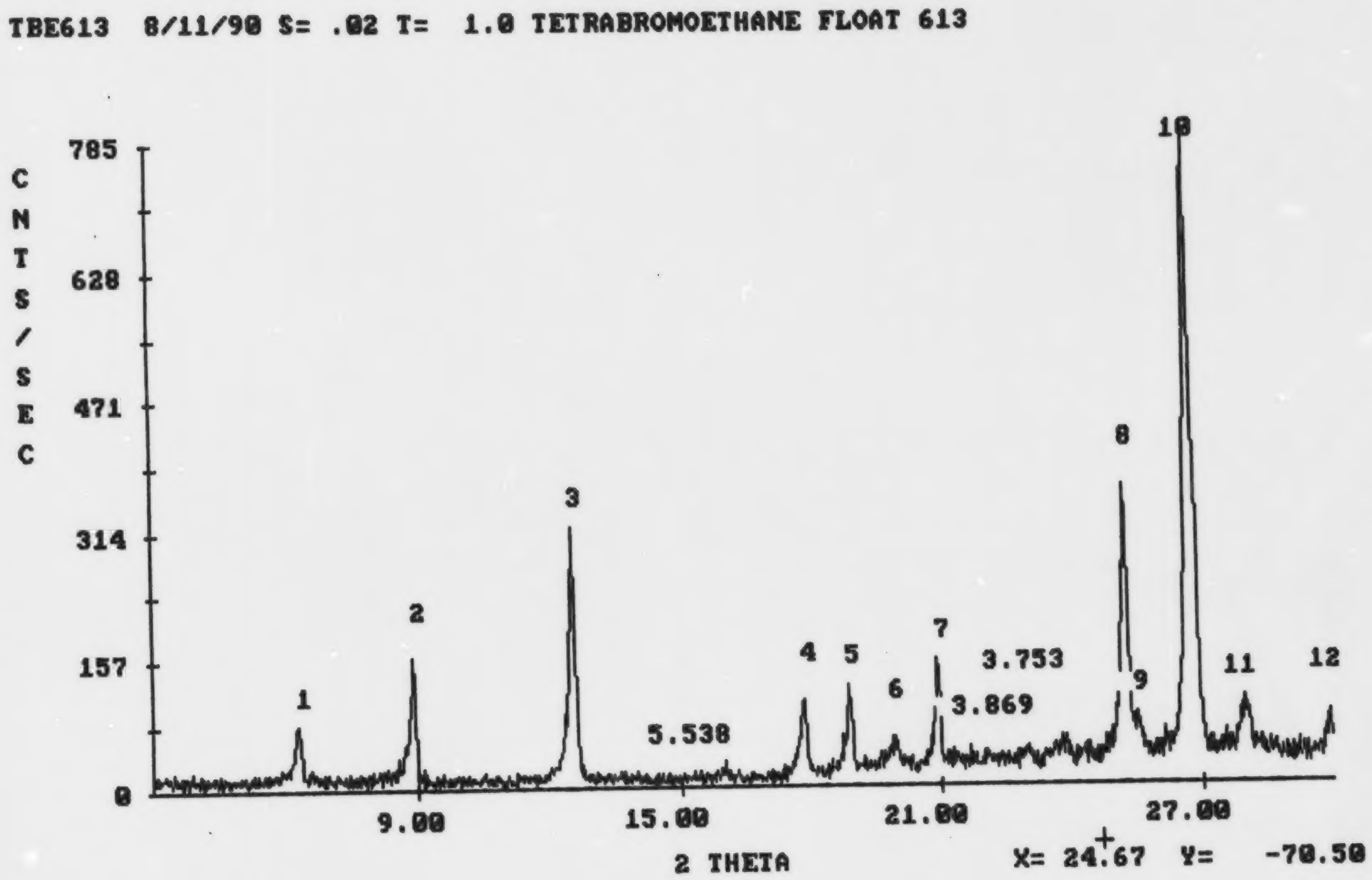
* = Obscured <..> = Missing [..] = Previously Removed

TBE316 8/11/90 S= .02 T= 1.0 TETRABROMOETHANE FLOAT 316

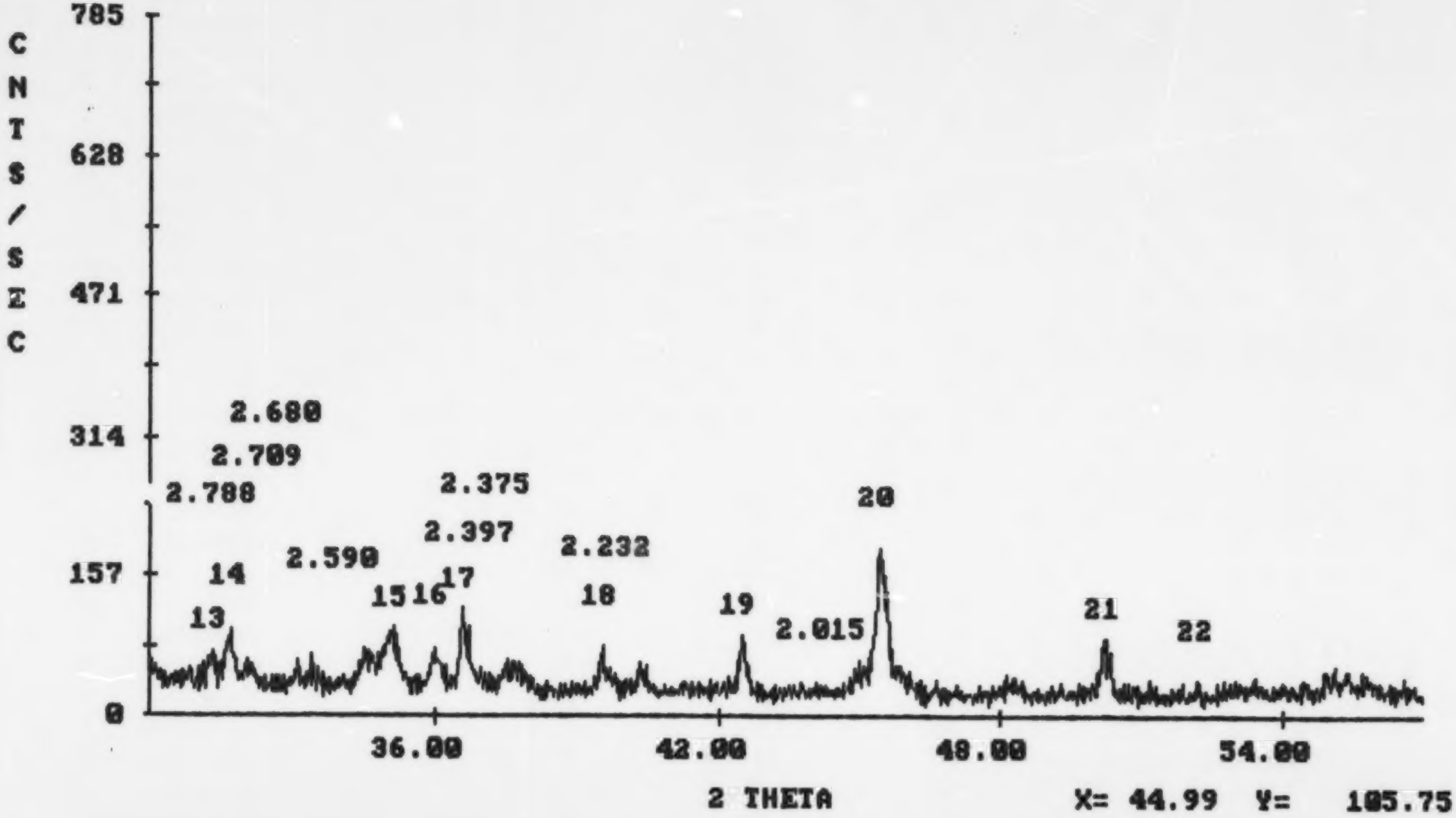



TBE316 8/11/90 S= .02 T= 1.0 TETRABROMOETHANE FLOAT 316
CNTS/SEC
987
790
592
395
197
0
9.00
15.00
21.00
27.00
2 THETA
X= 24.52 Y= -115.92
1
2
3
4
5
6
7
3.874
8
9
10
11
12
13
14
15
16

```
 3903  8-11-90        TETRABROMOETHANE FLOAT 316   TIME=  1.0 TUBE=CU LAMDA= 1.542
START ANGLE=   3.000   DELTA 2THETA=   .020    SENS=5.00  CENTROID= 7 NTP= 5
SM= 0  BKGR= 0 0 0  KA2=0  TUBE=CU SCH= 9

 N   2THETA   DSPACE  (1/D**2)  HEIGHT    AREA      P      W2     W4

 1    6.317  13.9914    .0051     67.      7.     34.   .117   .097
 2    8.918   9.9158    .0102    177.     20.    130.   .141   .113
 3   12.574   7.0394    .0202    249.     28.    200.   .141   .112
 4   17.805   4.9813    .0403    138.     19.    120.   .164   .138
 5   18.867   4.7033    .0452    112.     11.     66.   .117   .098
 6   19.920   4.4570    .0503     65.      8.     18.   .141   .123
 7   20.922   4.2458    .0555    167.     19.    125.   .141   .115
 8   23.657   3.7607    .0707     47.      7.     15.   .164   .141
 9   23.844   3.7316    .0718     55.      7.     18.   .141   .118
10   25.241   3.5282    .0803    305.     43.    225.   .164   .142
11   25.557   3.4854    .0823    110.     10.     18.   .117   .087
12   26.719   3.3363    .0898    987.    123.    590.   .141   .124
~~13   26.736   3.3342    .0900    585.     44.     20.   .094   .075~~
14   27.499   3.2434    .0951     65.      7.     21.   .117   .100
15   27.923   3.1951    .0980    145.     29.    123.   .235   .202
16   29.974   2.9810    .1125     96.     17.     49.   .211   .173
17   31.285   2.8591    .1223     98.      9.     34.   .117   .092
18   31.664   2.8256    .1252     87.     14.     51.   .188   .160
19   32.081   2.7899    .1285     68.     10.     33.   .164   .146
20   35.022   2.5620    .1523    123.     29.     92.   .282   .233
21   36.038   2.4921    .1610     86.      9.     23.   .117   .102
22   36.656   2.4515    .1664    111.     21.     78.   .211   .186
23   39.541   2.2790    .1925     85.      9.     35.   .117   .105
24   42.486   2.1276    .2209    108.     12.     49.   .141   .113
25   45.442   1.9959    .2510    272.     28.    117.   .117   .105
26   46.623   1.9480    .2635     35.      6.     16.   .188   .167
27   47.482   1.9148    .2728     31.      5.     19.   .188   .149
28   50.203   1.8172    .3028    144.     14.     88.   .117   .098
29   55.382   1.6589    .3634     63.      5.     14.   .094   .083
```


TBE613 8/11/90 S= .02 T= 1.0 TETRABROMOETHANE FLOAT 613
CNTS/SEC
785
628
471
314
157
0
1
2
3
5.538
4
5
6
7
3.753
3.869
8
9
10
11
12
9.00
15.00
21.00
27.00
2 THETA
X= 24.67 Y= -70.50

TBE613 8/11/90 S= .02 T= 1.0 TETRABROMOETHANE FLOAT 613



```
 3903   8-11-90        TETRABROMOETHANE FLOAT 613
START  ANGLE=     3.000  DELTA 2THETA=    .020  TIME=  1.0 TUBE=CU LAMDA= 1.542
SM= 0   BKGR= 0 0 0  KA2=0  TUBE=CU SCH= 9 SENS=5.00  CENTROID= 7 NTP= 5

  N    2THETA   DSPACE  (1/D**2)  HEIGHT     AREA      P     W2    W4

  1     6.312  14.0021    .0051     77.       11.     60.  .164  .138
  2     8.912   9.9217    .0102    160.       17.    128.  .141  .109
  3    12.558   7.0486    .0201    320.       41.    287.  .164  .129
  4    17.832   4.9741    .0404    104.       16.     94.  .188  .155
  5    18.863   4.7043    .0452    124.       14.     88.  .141  .116
  6    19.861   4.4702    .0500     59.       12.     39.  .258  .203
  7    20.902   4.2497    .0554    154.       17.    104.  .141  .112
  8    25.224   3.5306    .0802    364.       49.    280.  .164  .134
  9    25.501   3.4928    .0820     88.       11.     19.  .141  .121
 10    26.701   3.3386    .0897    785.      108.    561.  .164  .138
 11    27.960   3.1910    .0982    105.       25.     80.  .282  .241
 12    29.919   2.9864    .1121     88.       10.     29.  .141  .113
 13    31.320   2.8559    .1226     71.       11.     30.  .188  .161
 14    31.716   2.8211    .1256     96.       17.     55.  .211  .175
 15    35.118   2.5553    .1532     98.       20.     43.  .235  .205
 16    36.000   2.4947    .1607     75.       15.     39.  .235  .195
 17    36.583   2.4562    .1658    119.       12.     42.  .117  .101
 18    39.537   2.2793    .1925     76.        9.     32.  .141  .119
 19    42.484   2.1277    .2209     90.       10.     38.  .141  .110
 20    45.441   1.9959    .2510    189.       40.    167.  .258  .211
 21    50.215   1.8168    .3030     87.        8.     27.  .094  .087
 22    52.184   1.7528    .3255     40.        4.     16.  .117  .096
```

APPENDIX VI: DATA FOR THE STATISTICAL ANALYSIS TO DETERMINE COUNTING CRITERION (Sample 260-1)

Dial Number	Mineral /Group	0-50 (1)	50-100 (2)	100-150 (3)	150-200 (4)	200-250 (5)	250-300 (6)	300-350 (7)	350-400 (8)	Mean	Stnd Dev
1	tourmaline	0	0	0	0	0	0	1	1	0.25	0.43
2	hem/geoth	14	22	21	13	19	9	19	21	17.25	4.38
3	ilmen/mag	1	0	0	2	1	2	0	2	1.00	0.87
4	clear garnet	8	6	9	7	2	6	7	8	6.63	2.00
5	amphibole	1	1	3	1	1	0	1	3	1.38	0.99
6	unk/oth tran	10	6	6	7	10	11	2	1	6.63	3.46
7	clear zircon	0	0	0	0	0	1	1	0	0.25	0.43
8	sillim/fibro	3	0	0	1	0	1	1	0	0.75	0.97
9	unk/oth opaq	3	2	4	2	5	8	6	5	4.38	1.93
10	green garnet	0	0	0	0	1	1	0	0	0.25	0.43
11	garnet aggr	10	13	7	17	10	11	12	8	11.00	2.92
12	epidote grp	0	0	0	0	0	0	0	1	0.13	0.33
13	zoned zircon	0	0	0	0	1	0	0	0	0.13	0.33
14	blank	0	0	0	0	0	0	0	0	0.00	0.00
	totals =	50	50	50	50	50	50	50	50		

Dial Number	Mineral /Group	0-50 (1)	50-100 (2)	100-150 (3)	150-200 (4)	200-250 (5)	250-300 (6)	300-350 (7)	350-400 (8)	Mean	Stnd Dev
1	tourmaline	0	0	0	0	0	0	2	2	0.50	0.87
2	hem/geoth	28	44	42	26	38	18	38	42	34.50	8.76
3	ilmen/mag	2	0	0	4	2	4	0	4	2.00	1.73
4	clear garnet	16	12	18	14	4	12	14	16	13.25	3.99
5	amphibole	2	2	6	2	2	0	2	6	2.75	1.98
6	unk/oth tran	20	12	12	14	20	22	4	2	13.25	6.92
7	clear zircon	0	0	0	0	0	2	2	0	0.50	0.87
8	sillim/fibro	6	0	0	2	0	2	2	0	1.50	1.94
9	unk/oth opaq	6	4	8	4	10	16	12	10	8.75	3.86
10	green garnet	0	0	0	0	2	2	0	0	0.50	0.87
11	garnet aggr	20	26	14	34	20	22	24	16	22.00	5.83
12	epidote grp	0	0	0	0	0	0	0	2	0.25	0.66
13	zoned zircon	0	0	0	0	2	0	0	0	0.25	0.66
14	blank	0	0	0	0	0	0	0	0	0.00	0.00
	totals =	100	100	100	100	100	100	100	100		

APPENDIX VI: DATA FOR THE STATISTICAL ANALYSIS TO DETERMINE COUNTING CRITERION (Sample 260–1)

Mineral /Group	A (1+2)	B (3+4)	C (5+6)	D (7+8)	Mean	Stnd Dev
tourmaline	0	0	0	2	0.50	0.87
hem/geoth	36	34	28	40	34.50	4.33
ilmen/mag	1	2	3	2	2.00	0.71
clear garnet	14	16	8	15	13.25	3.11
amphibole	2	4	1	4	2.75	1.30
unk/oth tran	16	13	21	3	13.25	6.57
clear zircon	0	0	1	1	0.50	0.50
sillim/fibro	3	1	1	1	1.50	0.87
unk/oth opaq	5	6	13	11	8.75	3.34
green garnet	0	0	2	0	0.50	0.87
garnet aggr	23	24	21	20	22.00	1.58
epidote grp	0	0	0	1	0.25	0.43
zoned zircon	0	0	1	0	0.25	0.43
totals =	100	100	100	100		

Mineral /Group	I (A+B)	II (A+C)	III (A+D)	IV (B+C)	V (B+D)	VI (C+D)	Mean	Stnd Dev
tourmaline	0	0	2	0	2	2	1.00	1.00
hem/geoth	70	64	76	62	74	68	69.00	5.00
ilmen/mag	3	4	3	5	4	5	4.00	0.82
clear garnet	30	22	29	24	31	23	26.50	3.59
amphibole	6	3	6	5	8	5	5.50	1.50
unk/oth tran	29	37	19	34	16	24	26.50	7.59
clear zircon	0	1	1	1	1	2	1.00	0.58
sillim/fibro	4	4	4	2	2	2	3.00	1.00
unk/oth opaq	11	18	16	19	17	24	17.50	3.86
green garnet	0	2	0	2	0	2	1.00	1.00
garnet aggr	47	44	43	45	44	41	44.00	1.83
epidote grp	0	0	1	0	1	1	0.50	0.50
zoned zircon	0	1	0	1	0	1	0.50	0.50
totals =	200	200	200	200	200	200		

APPENDIX VI: DATA FOR THE STATISTICAL ANALYSIS TO DETERMINE COUNTING CRITERION (Sample 260-1)

Dial Number	Mineral /Group	I (A+B)	II (A+C)	III (A+D)	IV (B+C)	V (B+D)	VI (C+D)	Mean	Stnd Dev
1	tourmaline	0	0	1	0	1	1	0.50	0.50
2	hem/geoth	35	32	38	31	37	34	34.50	2.50
3	ilmen/mag	1.5	2	1.5	2.5	2	2.5	2.00	0.41
4	clear garnet	15	11	14.5	12	15.5	11.5	13.25	1.80
5	amphibole	3	1.5	3	2.5	4	2.5	2.75	0.75
6	unk/oth tran	14.5	18.5	9.5	17	8	12	13.25	3.79
7	clear zircon	0	0.5	0.5	0.5	0.5	1	0.50	0.29
8	sillim/fibro	2	2	2	1	1	1	1.50	0.50
9	unk/oth opaq	5.5	9	8	9.5	8.5	12	8.75	1.93
10	green garnet	0	1	0	1	0	1	0.50	0.50
11	garnet aggr	23.5	22	21.5	22.5	22	20.5	22.00	0.91
12	epidote grp	0	0	0.5	0	0.5	0.5	0.25	0.25
13	zoned zircon	0	0.5	0	0.5	0	0.5	0.25	0.25
	totals =	100	100	100	100	100	100		

Dial Number	Mineral /Group	cumul. % at 50	cumul. % at 100	cumul. % at 150	cumul. % at 200	cumul. % at 250	cumul. % at 300	cumul. % at 350	cumul. % at 400	Mean	Stnd Dev
1	tourmaline	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%	0.5%	0.1%	0.2%
2	hem/geoth	28.0%	36.0%	38.0%	35.0%	35.6%	32.7%	33.4%	34.5%	34.1%	2.8%
3	ilmen/mag	2.0%	1.0%	0.7%	1.5%	1.6%	2.0%	1.7%	2.0%	1.6%	0.5%
4	clear garnet	16.0%	14.0%	15.3%	15.0%	12.8%	12.7%	12.9%	13.3%	14.0%	1.2%
5	amphibole	2.0%	2.0%	3.3%	3.0%	2.8%	2.3%	2.3%	2.8%	2.6%	0.5%
6	unk/oth tran	20.0%	16.0%	14.7%	14.5%	15.6%	16.7%	14.9%	13.3%	15.7%	1.9%
7	clear zircon	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%	0.6%	0.5%	0.2%	0.2%
8	sillim/fibro	6.0%	3.0%	2.0%	2.0%	1.6%	1.7%	1.7%	1.5%	2.4%	1.4%
9	unk/oth opaq	6.0%	5.0%	6.0%	5.5%	6.4%	8.0%	8.6%	8.8%	6.8%	1.4%
10	green garnet	0.0%	0.0%	0.0%	0.0%	0.4%	0.7%	0.6%	0.5%	0.3%	0.3%
11	garnet aggr	20.0%	23.0%	20.0%	23.5%	22.8%	22.7%	22.9%	22.0%	22.1%	1.3%
12	epidote grp	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%	0.0%	0.1%
13	zoned zircon	0.0%	0.0%	0.0%	0.0%	0.4%	0.3%	0.3%	0.3%	0.2%	0.2%
	totals =	100%	100%	100%	100%	100%	100%	100%	100%		

APPENDIX VI: DATA FOR THE STATISTICAL ANALYSIS TO DETERMINE COUNTING CRITERION (Sample 276-1)

Dial Number	Mineral /Group	0-50 (1)	50-100 (2)	100-150 (3)	150-200 (4)	200-250 (5)	250-300 (6)	300-350 (7)	350-400 (8)	Mean	Stnd Dev
1	tourmaline	0	0	0	0	0	0	0	0	0.0	0.0
2	hem/geoth	5	6	7	9	3	9	7	6	6.5	1.9
3	ilmen/mag	0	2	0	0	0	0	0	1	0.4	0.7
4	clear garnet	29	30	31	30	33	28	23	30	29.3	2.7
5	amphibole	0	0	0	0	0	0	0	0	0.0	0.0
6	unk/oth tran	2	2	3	0	4	3	4	3	2.6	1.2
7	clear zircon	0	0	0	0	0	0	0	0	0.0	0.0
8	sillim/fibro	0	0	0	0	0	0	0	0	0.0	0.0
9	unk/oth opaq	1	0	1	0	0	1	3	1	0.9	0.9
10	green garnet	2	0	2	3	2	1	3	2	1.9	0.9
11	garnet aggr	11	10	6	8	8	8	10	7	8.5	1.6
12	epidote grp	0	0	0	0	0	0	0	0	0.0	0.0
13	zoned zircon	0	0	0	0	0	0	0	0	0.0	0.0
	totals =	50	50	50	50	50	50	50	50		

Dial Number	Mineral /Group	0-50 (1)	50-100 (2)	100-150 (3)	150-200 (4)	200-250 (5)	250-300 (6)	300-350 (7)	350-400 (8)	Mean	Stnd Dev
1	tourmaline	0	0	0	0	0	0	0	0	0.0	0.0
2	hem/geoth	10	12	14	18	6	18	14	12	13.0	3.7
3	ilmen/mag	0	4	0	0	0	0	0	2	0.8	1.4
4	clear garnet	58	60	62	60	66	56	46	60	58.5	5.5
5	amphibole	0	0	0	0	0	0	0	0	0.0	0.0
6	unk/oth tran	4	4	6	0	8	6	8	6	5.3	2.4
7	clear zircon	0	0	0	0	0	0	0	0	0.0	0.0
8	sillim/fibro	0	0	0	0	0	0	0	0	0.0	0.0
9	unk/oth opaq	2	0	2	0	0	2	6	2	1.8	1.9
10	green garnet	4	0	4	6	4	2	6	4	3.8	1.9
11	garnet aggr	22	20	12	16	16	16	20	14	17.0	3.2
12	epidote grp	0	0	0	0	0	0	0	0	0.0	0.0
13	zoned zircon	0	0	0	0	0	0	0	0	0.0	0.0
	totals =	100	100	100	100	100	100	100	100		

APPENDIX VI: DATA FOR THE STATISTICAL ANALYSIS TO DETERMINE COUNTING CRITERION (Sample 276–1)

Dial Number	Mineral /Group	A (1+2)	B (3+4)	C (5+6)	D (7+8)	Mean	Stnd Dev
1	tourmaline	0	0	0	0	0.0	0.0
2	hem/geoth	11	16	12	13	13.0	1.9
3	ilmen/mag	2	0	0	1	0.8	0.8
4	clear garnet	59	61	61	53	58.5	3.3
5	amphibole	0	0	0	0	0.0	0.0
6	unk/oth tran	4	3	7	7	5.3	1.8
7	clear zircon	0	0	0	0	0.0	0.0
8	sillim/fibro	0	0	0	0	0.0	0.0
9	unk/oth opaq	1	1	1	4	1.8	1.3
10	green garnet	2	5	3	5	3.8	1.3
11	garnet aggr	21	14	16	17	17.0	2.5
12	epidote grp	0	0	0	0	0.0	0.0
13	zoned zircon	0	0	0	0	0.0	0.0
	totals =	100	100	100	100		

Dial Number	Mineral /Group	I (A+B)	II (A+C)	III (A+D)	IV (B+C)	V (B+D)	VI (C+D)	Mean	Stnd Dev
1	tourmaline	0	0	0	0	0	0	0.00	0.00
2	hem/geoth	27	23	24	28	29	25	26.00	2.16
3	ilmen/mag	2	2	3	0	1	1	1.50	0.96
4	clear garnet	120	120	112	122	114	114	117.00	3.79
5	amphibole	0	0	0	0	0	0	0.00	0.00
6	unk/oth tran	7	11	11	10	10	14	10.50	2.06
7	clear zircon	0	0	0	0	0	0	0.00	0.00
8	sillim/fibro	0	0	0	0	0	0	0.00	0.00
9	unk/oth opaq	2	2	5	2	5	5	3.50	1.50
10	green garnet	7	5	7	8	10	8	7.50	1.50
11	garnet aggr	35	37	38	30	31	33	34.00	2.94
12	epidote grp	0	0	0	0	0	0	0.00	0.00
13	zoned zircon	0	0	0	0	0	0	0.00	0.00
	totals =	200	200	200	200	200	200		

APPENDIX VI: DATA FOR THE STATISTICAL ANALYSIS TO DETERMINE COUNTING CRITERION (Sample 276-1)

Dial Number	Mineral /Group		I (A+B)	II (A+C)	III (A+D)	IV (B+C)	V (B+D)	VI (C+D)	Mean	Stnd Dev
1	tourmaline		0	0	0	0	0	0	0.00	0.00
2	hem/geoth		13.5	11.5	12	14	14.5	12.5	13.00	1.08
3	ilmen/mag		1	1	1.5	0	0.5	0.5	0.75	0.48
4	clear garnet		60	60	56	61	57	57	58.50	1.89
5	amphibole		0	0	0	0	0	0	0.00	0.00
6	unk/oth tran		3.5	5.5	5.5	5	5	7	5.25	1.03
7	clear zircon		0	0	0	0	0	0	0.00	0.00
8	sillim/fibro		0	0	0	0	0	0	0.00	0.00
9	unk/oth opaq		1	1	2.5	1	2.5	2.5	1.75	0.75
10	green garnet		3.5	2.5	3.5	4	5	4	3.75	0.75
11	garnet aggr		17.5	18.5	19	15	15.5	16.5	17.00	1.47
12	epidote grp		0	0	0	0	0	0	0.00	0.00
13	zoned zircon		0	0	0	0	0	0	0.00	0.00
		totals =	100	100	100	100	100	100		

Dial Number	Mineral /Group		cumul. % at 50	cumul. % at 100	cumul. % at 150	cumul. % at 200	cumul. % at 250	cumul. % at 300	cumul. % at 350	cumul. % at 400	Mean	Stnd Dev
1	tourmaline		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2	hem/geoth		10.0%	11.0%	12.0%	13.5%	12.0%	13.0%	13.1%	13.0%	12.2%	1.1%
3	ilmen/mag		0.0%	2.0%	1.3%	1.0%	0.8%	0.7%	0.6%	0.8%	0.9%	0.5%
4	clear garnet		58.0%	59.0%	60.0%	60.0%	61.2%	60.3%	58.3%	58.5%	59.4%	1.1%
5	amphibole		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
6	unk/oth tran		4.0%	4.0%	4.7%	3.5%	4.4%	4.7%	5.1%	5.3%	4.5%	0.6%
7	clear zircon		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
8	sillim/fibro		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
9	unk/oth opaq		2.0%	1.0%	1.3%	1.0%	0.8%	1.0%	1.7%	1.8%	1.3%	0.4%
10	green garnet		4.0%	2.0%	2.7%	3.5%	3.6%	3.3%	3.7%	3.8%	3.3%	0.6%
11	garnet aggr		22.0%	21.0%	18.0%	17.5%	17.2%	17.0%	17.4%	17.0%	18.4%	1.8%
12	epidote grp		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
13	zoned zircon		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		totals =	100%	100%	100%	100%	100%	100%	100%	100%		

APPENDIX VI: DATA FOR THE STATISTICAL ANALYSIS TO DETERMINE COUNTING CRITERION (Sample 5022-C)

Dial Number	Mineral /Group		# grains 0-50 (1)	# grains 50-100 (2)	# grains 100-150 (3)	# grains 150-200 (4)	# grains 200-250 (5)	# grains 250-300 (6)	# grains 300-350 (7)	# grains 350-400 (8)	Mean	Stnd Dev
1	tourmaline		1	1	0	0	0	0	2	1	0.63	0.70
2	hem/geoth		15	15	19	20	19	21	22	17	18.50	2.45
3	ilmen/mag		6	8	4	2	3	3	4	5	4.38	1.80
4	clear garnet		2	5	4	6	6	6	3	2	4.25	1.64
5	amphibole		3	3	4	4	3	3	4	6	3.75	0.97
6	unk/oth tran		12	6	11	10	11	10	9	10	9.88	1.69
7	clear zircon		0	0	0	0	0	0	0	0	0.00	0.00
8	sillim/fibro		0	0	0	0	0	1	0	0	0.13	0.33
9	unk/oth opaq		7	7	5	4	3	3	2	4	4.38	1.73
10	green garnet		0	0	0	0	0	0	0	0	0.00	0.00
11	garnet aggr		2	4	3	4	4	2	4	4	3.38	0.86
12	epidote grp		1	1	0	0	1	0	0	0	0.38	0.48
13	zoned zircon		1	0	0	0	0	1	0	1	0.38	0.48
		totals =	50	50	50	50	50	50	50	50		

Dial Number	Mineral /Group		0-50 (1)	50-100 (2)	100-150 (3)	150-200 (4)	200-250 (5)	250-300 (6)	300-350 (7)	350-400 (8)	Mean	Stnd Dev
1	tourmaline		2	2	0	0	0	0	4	2	1.25	1.39
2	hem/geoth		30	30	38	40	38	42	44	34	37.00	4.90
3	ilmen/mag		12	16	8	4	6	6	8	10	8.75	3.60
4	clear garnet		4	10	8	12	12	12	6	4	8.50	3.28
5	amphibole		6	6	8	8	6	6	8	12	7.50	1.94
6	unk/oth tran		24	12	22	20	22	20	18	20	19.75	3.38
7	clear zircon		0	0	0	0	0	0	0	0	0.00	0.00
8	sillim/fibro		0	0	0	0	0	2	0	0	0.25	0.66
9	unk/oth opaq		14	14	10	8	6	6	4	8	8.75	3.46
10	green garnet		0	0	0	0	0	0	0	0	0.00	0.00
11	garnet aggr		4	8	6	8	8	4	8	8	6.75	1.71
12	epidote grp		2	2	0	0	2	0	0	0	0.75	0.97
13	zoned zircon		2	0	0	0	0	2	0	2	0.75	0.97
		totals =	100	100	100	100	100	100	100	100		

APPENDIX VI: DATA FOR THE STATISTICAL ANALYSIS TO DETERMINE COUNTING CRITERION (Sample 5022-C)

Dial Number	Mineral /Group		A (1+2)	B (3+4)	C (5+6)	D (7+8)	Mean	Stnd Dev
1	tourmaline		2	0	0	3	1.25	1.30
2	hem/geoth		30	39	40	39	37.00	4.06
3	ilmen/mag		14	6	6	9	8.75	3.27
4	clear garnet		7	10	12	5	8.50	2.69
5	amphibole		6	8	6	10	7.50	1.66
6	unk/oth tran		18	21	21	19	19.75	1.30
7	clear zircon		0	0	0	0	0.00	0.00
8	sillim/fibro		0	0	1	0	0.25	0.43
9	unk/oth opaq		14	9	6	6	8.75	3.27
10	green garnet		0	0	0	0	0.00	0.00
11	garnet aggr		6	7	6	8	6.75	0.83
12	epidote grp		2	0	1	0	0.75	0.83
13	zoned zircon		1	0	1	1	0.75	0.43
		totals =	100	100	100	100		

Dial Number	Mineral /Group		I (A+B)	II (A+C)	III (A+D)	IV (B+C)	V (B+D)	VI (C+D)	Mean	Stnd Dev
1	tourmaline		2	2	5	0	3	3	2.50	1.50
2	hem/geoth		69	70	69	79	78	79	74.00	4.69
3	ilmen/mag		20	20	23	12	15	15	17.50	3.77
4	clear garnet		17	19	12	22	15	17	17.00	3.11
5	amphibole		14	12	16	14	18	16	15.00	1.91
6	unk/oth tran		39	39	37	42	40	40	39.50	1.50
7	clear zircon		0	0	0	0	0	0	0.00	0.00
8	sillim/fibro		0	1	0	1	0	1	0.50	0.50
9	unk/oth opaq		23	20	20	15	15	12	17.50	3.77
10	green garnet		0	0	0	0	0	0	0.00	0.00
11	garnet aggr		13	12	14	13	15	14	13.50	0.96
12	epidote grp		2	3	2	1	0	1	1.50	0.96
13	zoned zircon		1	2	2	1	1	2	1.50	0.50
		totals =	200	200	200	200	200	200		

APPENDIX VI: DATA FOR THE STATISTICAL ANALYSIS TO DETERMINE COUNTING CRITERION (Sample 5022–C)

Dial Number	Mineral /Group	I (A+B)	II (A+C)	III (A+D)	IV (B+C)	V (B+D)	VI (C+D)	Mean	Stnd Dev
1	tourmaline	1	1	2.5	0	1.5	1.5	1.25	0.75
2	hem/geoth	34.5	35	34.5	39.5	39	39.5	37.00	2.35
3	ilmen/mag	10	10	11.5	6	7.5	7.5	8.75	1.89
4	clear garnet	8.5	9.5	6	11	7.5	8.5	8.50	1.55
5	amphibole	7	6	8	7	9	8	7.50	0.96
6	unk/oth tran	19.5	19.5	18.5	21	20	20	19.75	0.75
7	clear zircon	0	0	0	0	0	0	0.00	0.00
8	sillim/fibro	0	0.5	0	0.5	0	0.5	0.25	0.25
9	unk/oth opaq	11.5	10	10	7.5	7.5	6	8.75	1.89
10	green garnet	0	0	0	0	0	0	0.00	0.00
11	garnet aggr	6.5	6	7	6.5	7.5	7	6.75	0.48
12	epidote grp	1	1.5	1	0.5	0	0.5	0.75	0.48
13	zoned zircon	0.5	1	1	0.5	0.5	1	0.75	0.25
	totals =	100	100	100	100	100	100		

Dial Number	Mineral /Group	cumul. % at 50	cumul. % at 100	cumul. % at 150	cumul. % at 200	cumul. % at 250	cumul. % at 300	cumul. % at 350	cumul. % at 400	Mean	Stnd Dev
1	tourmaline	2.0%	2.0%	1.3%	1.0%	0.8%	0.7%	1.1%	1.3%	1.3%	0.5%
2	hem/geoth	30.0%	30.0%	32.7%	34.5%	35.2%	36.3%	37.4%	37.0%	34.1%	2.8%
3	ilmen/mag	12.0%	14.0%	12.0%	10.0%	9.2%	8.7%	8.6%	8.8%	10.4%	1.9%
4	clear garnet	4.0%	7.0%	7.3%	8.5%	9.2%	9.7%	9.1%	8.5%	7.9%	1.7%
5	amphibole	6.0%	6.0%	6.7%	7.0%	6.8%	6.7%	6.9%	7.5%	6.7%	0.5%
6	unk/oth tran	24.0%	18.0%	19.3%	19.5%	20.0%	20.0%	19.7%	19.8%	20.0%	1.6%
7	clear zircon	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
8	sillim/fibro	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%	0.3%	0.3%	0.1%	0.1%
9	unk/oth opaq	14.0%	14.0%	12.7%	11.5%	10.4%	9.7%	8.9%	8.8%	11.2%	2.0%
10	green garnet	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
11	garnet aggr	4.0%	6.0%	6.0%	6.5%	6.8%	6.3%	6.6%	6.8%	6.1%	0.8%
12	epidote grp	2.0%	2.0%	1.3%	1.0%	1.2%	1.0%	0.9%	0.8%	1.3%	0.5%
13	zoned zircon	2.0%	1.0%	0.7%	0.5%	0.4%	0.7%	0.6%	0.8%	0.8%	0.5%
	totals =	100%	100%	100%	100%	100%	100%	100%	100%		

APPENDIX VI: DATA FOR THE STATISTICAL ANALYSIS TO DETERMINE COUNTING CRITERION (Sample 5100-C)

Dial Number	Mineral /Group		0-50 (1)	50-100 (2)	100-150 (3)	150-200 (4)	200-250 (5)	250-300 (6)	300-350 (7)	350-400 (8)	Mean	Stnd Dev
1	tourmaline		0	1	0	0	0	1	1	1	0.50	0.50
2	hem/geoth		18	18	17	14	18	20	20	21	18.25	2.05
3	ilmen/mag		5	4	7	1	6	5	7	2	4.63	2.06
4	clear garnet		7	2	4	11	4	9	3	4	5.50	2.96
5	amphibole		7	4	1	2	1	1	1	4	2.63	2.06
6	unk/oth tran		6	9	8	5	5	2	4	4	5.38	2.12
7	clear zircon		0	1	0	1	1	2	3	2	1.25	0.97
8	sillim/fibro		0	0	0	0	0	1	0	0	0.13	0.33
9	unk/oth opaq		4	6	6	9	9	7	7	8	7.00	1.58
10	green garnet		0	0	0	0	2	0	0	0	0.25	0.66
11	garnet aggr		2	3	5	4	3	0	4	3	3.00	1.41
12	epidote grp		0	0	0	1	1	1	0	1	0.50	0.50
13	zoned zircon		1	2	2	2	0	1	0	0	1.00	0.87
		totals =	50	50	50	50	50	50	50	50		

Dial Number	Mineral /Group		0-50 (1)	50-100 (2)	100-150 (3)	150-200 (4)	200-250 (5)	250-300 (6)	300-350 (7)	350-400 (8)	Mean	Stnd Dev
1	tourmaline		0	2	0	0	0	2	2	2	1.00	1.00
2	hem/geoth		36	36	34	28	36	40	40	42	36.50	4.09
3	ilmen/mag		10	8	14	2	12	10	14	4	9.25	4.12
4	clear garnet		14	4	8	22	8	18	6	8	11.00	5.92
5	amphibole		14	8	2	4	2	2	2	8	5.25	4.12
6	unk/oth tran		12	18	16	10	10	4	8	8	10.75	4.24
7	clear zircon		0	2	0	2	2	4	6	4	2.50	1.94
8	sillim/fibro		0	0	0	0	0	2	0	0	0.25	0.66
9	unk/oth opaq		8	12	12	18	18	14	14	16	14.00	3.16
10	green garnet		0	0	0	0	4	0	0	0	0.50	1.32
11	garnet aggr		4	6	10	8	6	0	8	6	6.00	2.83
12	epidote grp		0	0	0	2	2	2	0	2	1.00	1.00
13	zoned zircon		2	4	4	4	0	2	0	0	2.00	1.73
		totals =	100	100	100	100	100	100	100	100		

APPENDIX VI: DATA FOR THE STATISTICAL ANALYSIS TO DETERMINE COUNTING CRITERION (Sample 5100–C)

Dial Number	Mineral /Group	A (1+2)	B (3+4)	C (5+6)	D (7+8)	Mean	Stnd Dev
1	tourmaline	1	0	1	2	1.00	0.71
2	hem/geoth	36	31	38	41	36.50	3.64
3	ilmen/mag	9	8	11	9	9.25	1.09
4	clear garnet	9	15	13	7	11.00	3.16
5	amphibole	11	3	2	5	5.25	3.49
6	unk/oth tran	15	13	7	8	10.75	3.34
7	clear zircon	1	1	3	5	2.50	1.66
8	sillim/fibro	0	0	1	0	0.25	0.43
9	unk/oth opaq	10	15	16	15	14.00	2.35
10	green garnet	0	0	2	0	0.50	0.87
11	garnet aggr	5	9	3	7	6.00	2.24
12	epidote grp	0	1	2	1	1.00	0.71
13	zoned zircon	3	4	1	0	2.00	1.58
	totals =	100	100	100	100		

Dial Number	Mineral /Group	I (A+B)	II (A+C)	III (A+D)	IV (B+C)	V (B+D)	VI (C+D)	Mean	Stnd Dev
1	tourmaline	1	2	3	1	2	3	2.00	0.82
2	hem/geoth	67	74	77	69	72	79	73.00	4.20
3	ilmen/mag	17	20	18	19	17	20	18.50	1.26
4	clear garnet	24	22	16	28	22	20	22.00	3.65
5	amphibole	14	13	16	5	8	7	10.50	4.03
6	unk/oth tran	28	22	23	20	21	15	21.50	3.86
7	clear zircon	2	4	6	4	6	8	5.00	1.91
8	sillim/fibro	0	1	0	1	0	1	0.50	0.50
9	unk/oth opaq	25	26	25	31	30	31	28.00	2.71
10	green garnet	0	2	0	2	0	2	1.00	1.00
11	garnet aggr	14	8	12	12	16	10	12.00	2.58
12	epidote grp	1	2	1	3	2	3	2.00	0.82
13	zoned zircon	7	4	3	5	4	1	4.00	1.83
	totals =	200	200	200	200	200	200		

APPENDIX VI: DATA FOR THE STATISTICAL ANALYSIS TO DETERMINE COUNTING CRITERION (Sample 5100–C)

Dial Number	Mineral /Group		I (A+B)	II (A+C)	III (A+D)	IV (B+C)	V (B+D)	VI (C+D)	Mean	Stnd Dev
1	tourmaline		0.5	1	1.5	0.5	1	1.5	1.00	0.41
2	hem/geoth		33.5	37	38.5	34.5	36	39.5	36.50	2.10
3	ilmen/mag		8.5	10	9	9.5	8.5	10	9.25	0.63
4	clear garnet		12	11	8	14	11	10	11.00	1.83
5	amphibole		7	6.5	8	2.5	4	3.5	5.25	2.02
6	unk/oth tran		14	11	11.5	10	10.5	7.5	10.75	1.93
7	clear zircon		1	2	3	2	3	4	2.50	0.96
8	sillim/fibro		0	0.5	0	0.5	0	0.5	0.25	0.25
9	unk/oth opaq		12.5	13	12.5	15.5	15	15.5	14.00	1.35
10	green garnet		0	1	0	1	0	1	0.50	0.50
11	garnet aggr		7	4	6	6	8	5	6.00	1.29
12	epidote grp		0.5	1	0.5	1.5	1	1.5	1.00	0.41
13	zoned zircon		3.5	2	1.5	2.5	2	0.5	2.00	0.91
		totals =	100	100	100	100	100	100		

Dial Number	Mineral /Group		cumul. % at 50	cumul. % at 100	cumul. % at 150	cumul. % at 200	cumul. % at 250	cumul. % at 300	cumul. % at 350	cumul. % at 400	Mean	Stnd Dev
1	tourmaline	:	0.0%	1.0%	0.7%	0.5%	0.4%	0.7%	0.9%	1.0%	0.6%	0.3%
2	hem/geoth		36.0%	36.0%	35.3%	33.5%	34.0%	35.0%	35.7%	36.5%	35.3%	1.0%
3	ilmen/mag		10.0%	9.0%	10.7%	8.5%	9.2%	9.3%	10.0%	9.3%	9.5%	0.6%
4	clear garnet		14.0%	9.0%	8.7%	12.0%	11.2%	12.3%	11.4%	11.0%	11.2%	1.6%
5	amphibole		14.0%	11.0%	8.0%	7.0%	6.0%	5.3%	4.9%	5.3%	7.7%	3.0%
6	unk/oth tran		12.0%	15.0%	15.3%	14.0%	13.2%	11.7%	11.1%	10.8%	12.9%	1.6%
7	clear zircon		0.0%	1.0%	0.7%	1.0%	1.2%	1.7%	2.3%	2.5%	1.3%	0.8%
8	sillim/fibro		0.0%	0.0%	0.0%	0.0%	0.0%	0.3%	0.3%	0.3%	0.1%	0.1%
9	unk/oth opaq		8.0%	10.0%	10.7%	12.5%	13.6%	13.7%	13.7%	14.0%	12.0%	2.1%
10	green garnet		0.0%	0.0%	0.0%	0.0%	0.8%	0.7%	0.6%	0.5%	0.3%	0.3%
11	garnet aggr		4.0%	5.0%	6.7%	7.0%	6.8%	5.7%	6.0%	6.0%	5.9%	0.9%
12	epidote grp		0.0%	0.0%	0.0%	0.5%	0.8%	1.0%	0.9%	1.0%	0.5%	0.4%
13	zoned zircon		2.0%	3.0%	3.3%	3.5%	2.8%	2.7%	2.3%	2.0%	2.7%	0.5%
		totals =	100%	100%	100%	100%	100%	100%	100%	100%		

APPENDIX VII

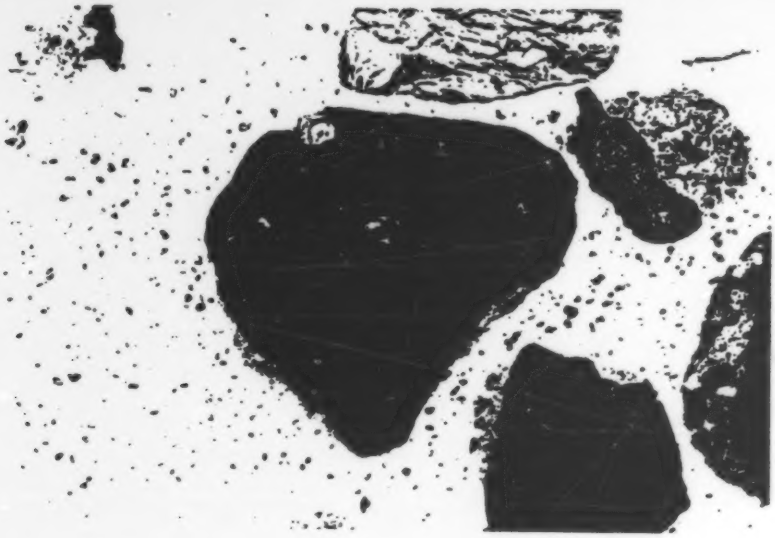


PLATE VII.1 Goethite with sulfide core in transmitted light

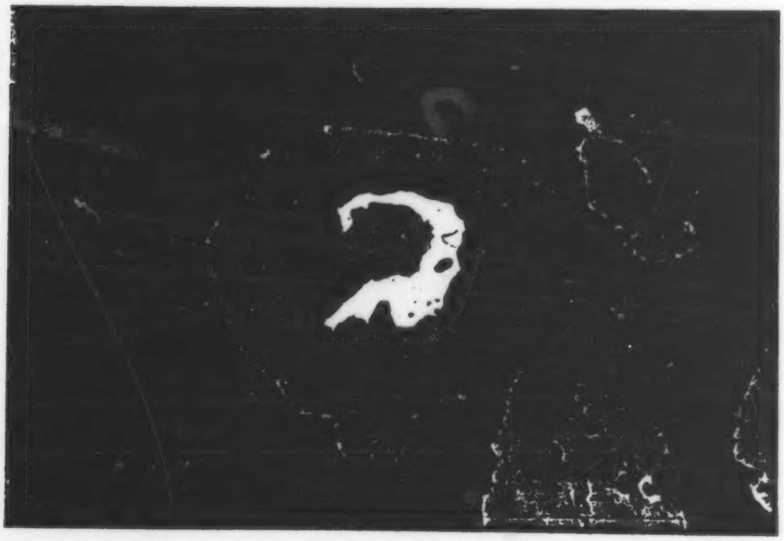


PLATE VII.2 Goethite with sulfide core in reflected light

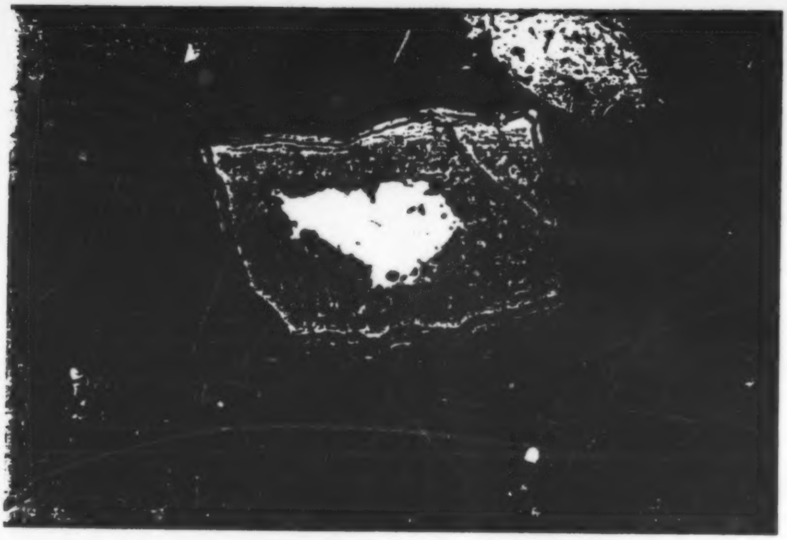


PLATE VII.3 Goethite with sulfide core in reflected light

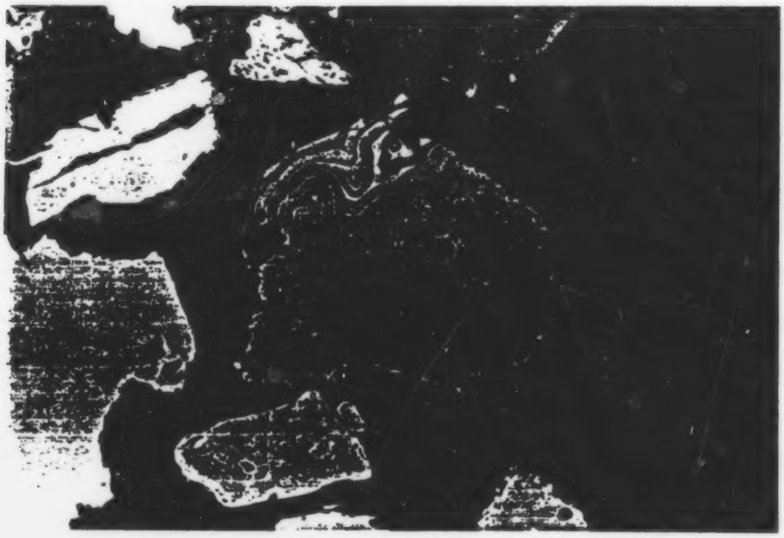


PLATE VII.4 Colloform mass of goethite in reflected light

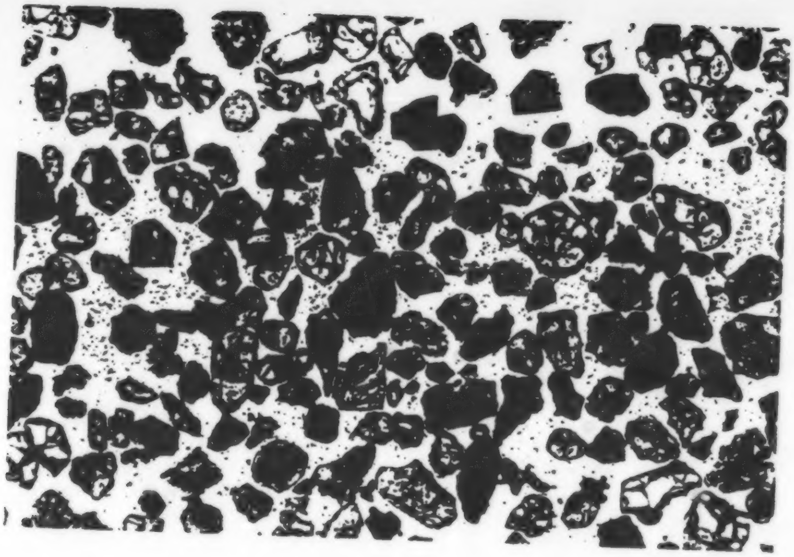


PLATE VII.5 Typical garnetiferous section in transmitted light

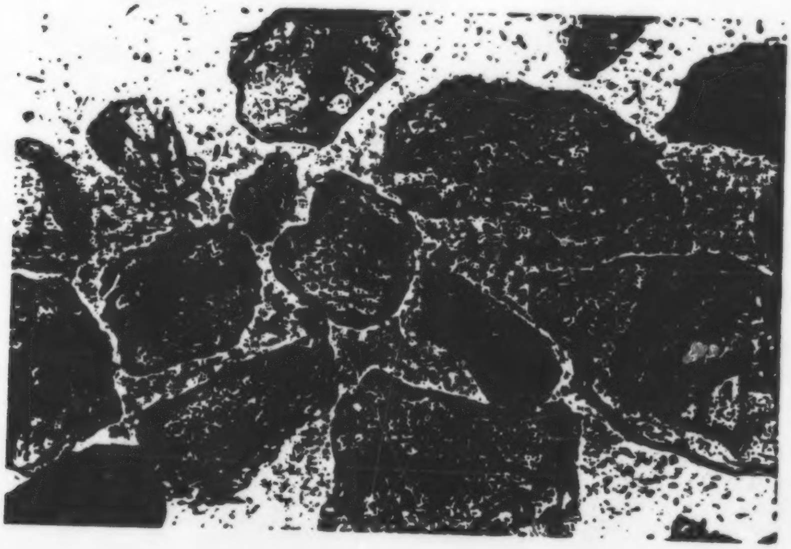


PLATE VII.6 Garnet with opaque inclusions

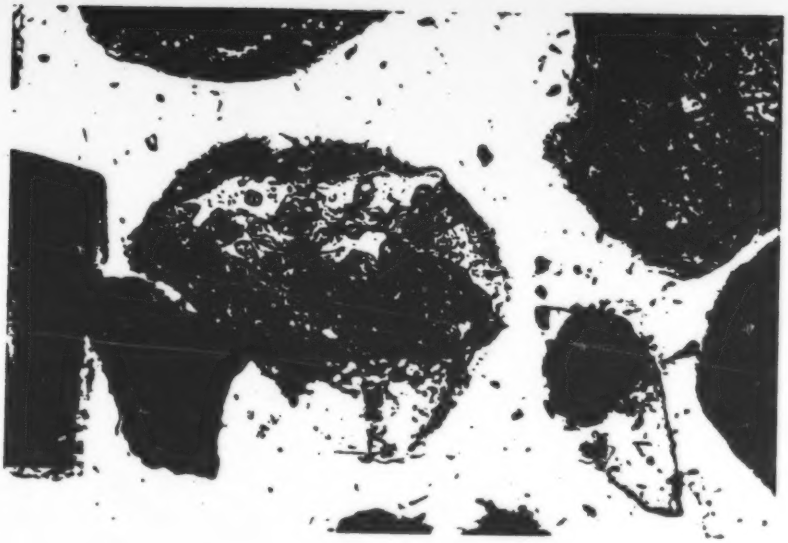


PLATE VII.7 Coticule in transmitted light

PLATE VII.8 Coticule in reflected light

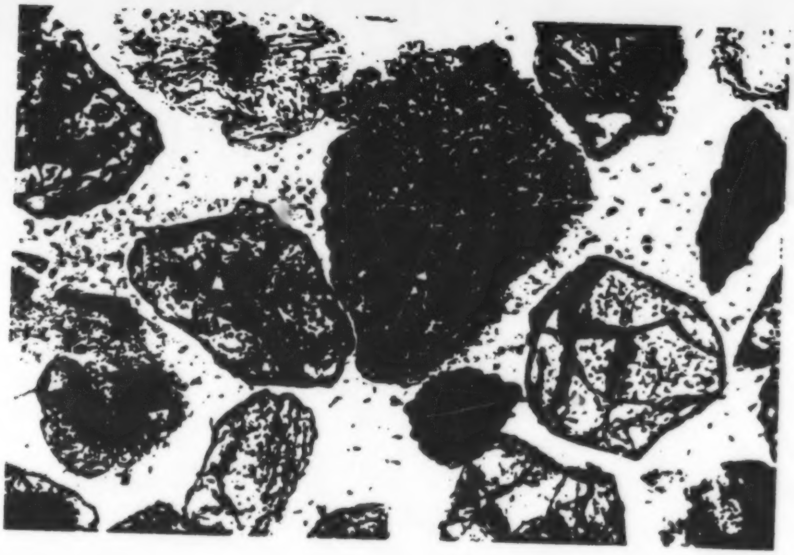


PLATE VII.9 Coticule with chloritic matrix

PLATE VII.10 Zoned and clear zircons

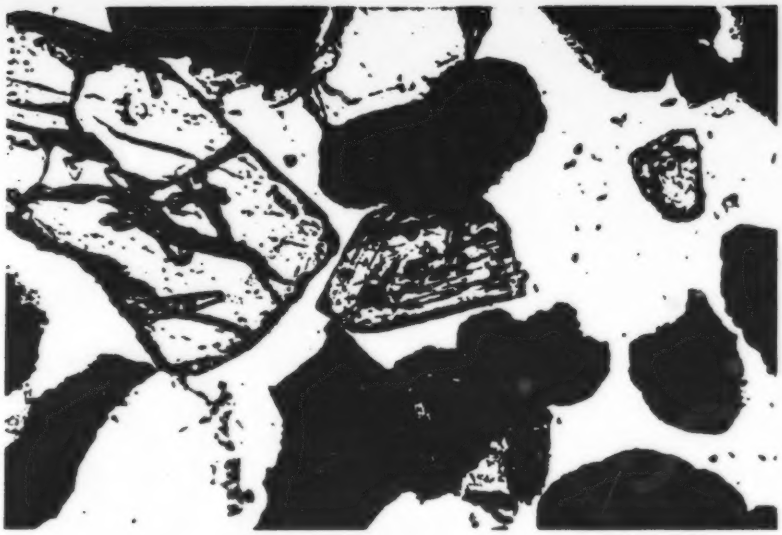


PLATE VII.11 Zoned zircon

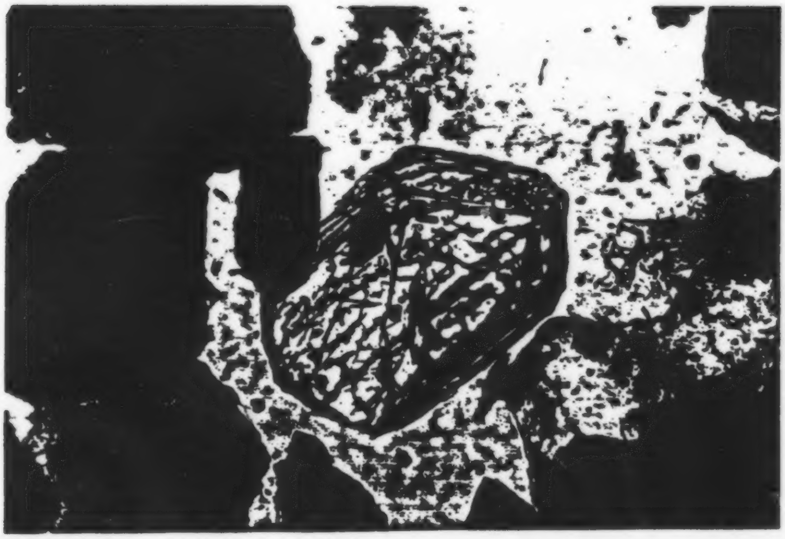


PLATE VII.12 Zoned zircon

PLATE VII.13 Fibrolite (sillimanite)

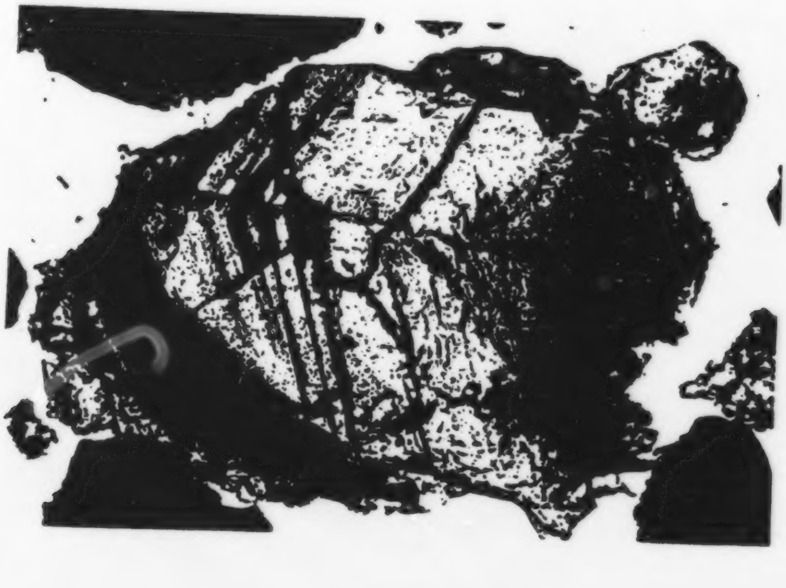


PLATE VII.14 Cassiterite

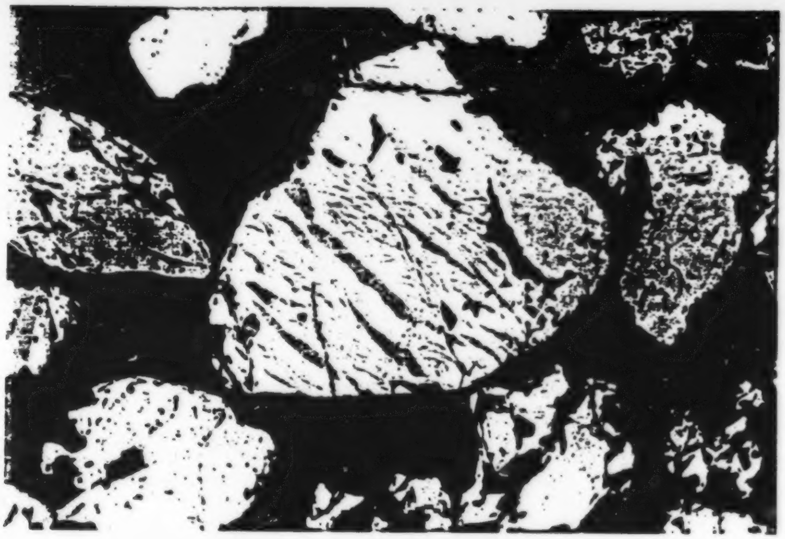


PLATE VII.15 Ilmenite

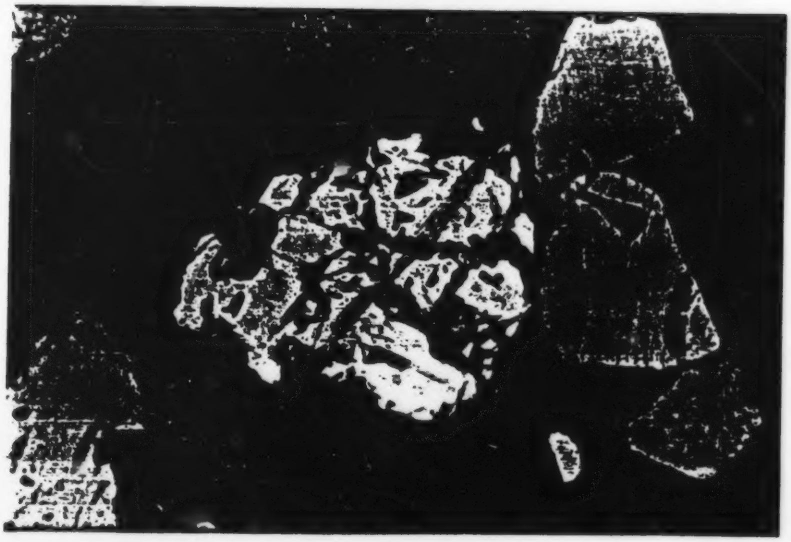


PLATE VII.16 Native Gold

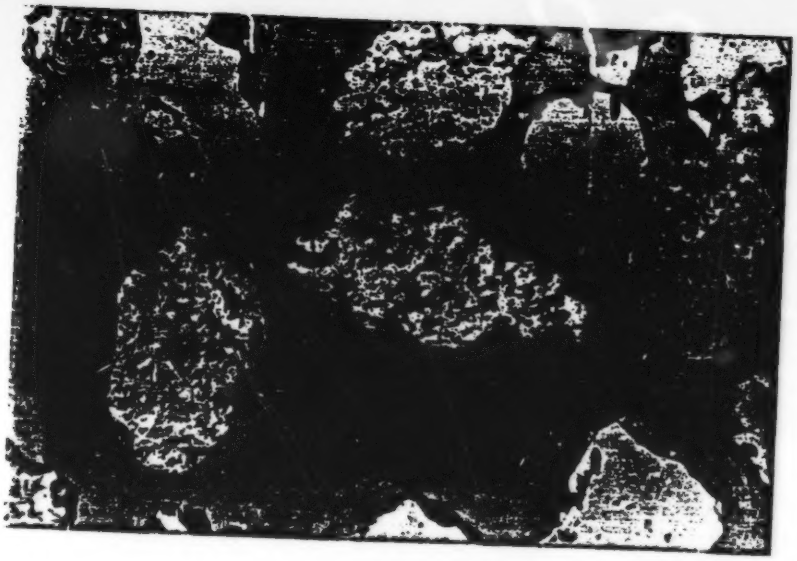


PLATE VII.17 Electrum

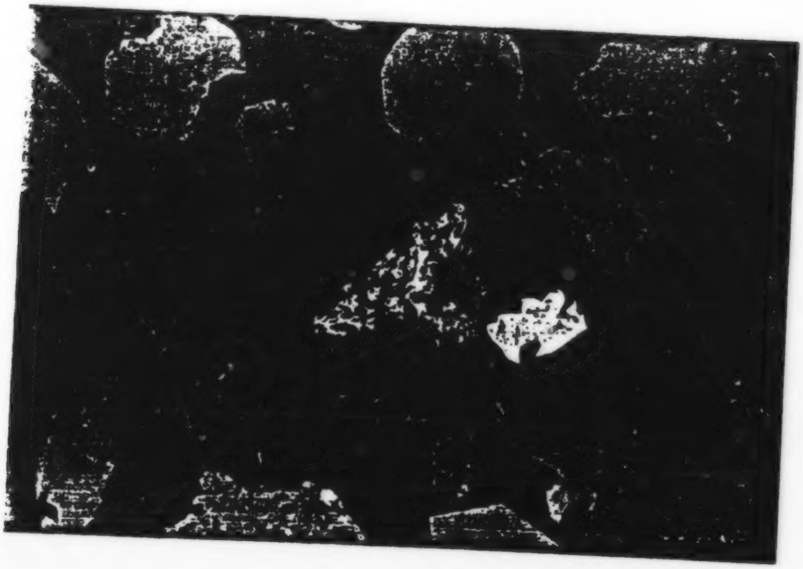


PLATE VII.18 Electrum

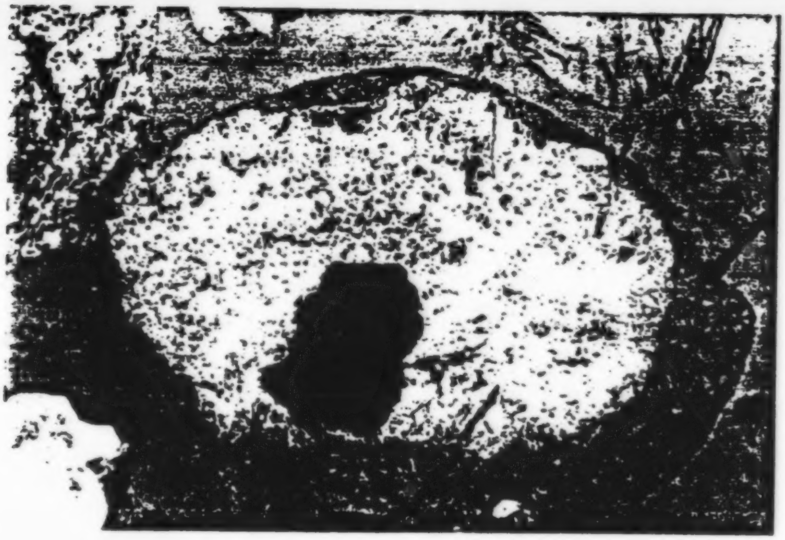
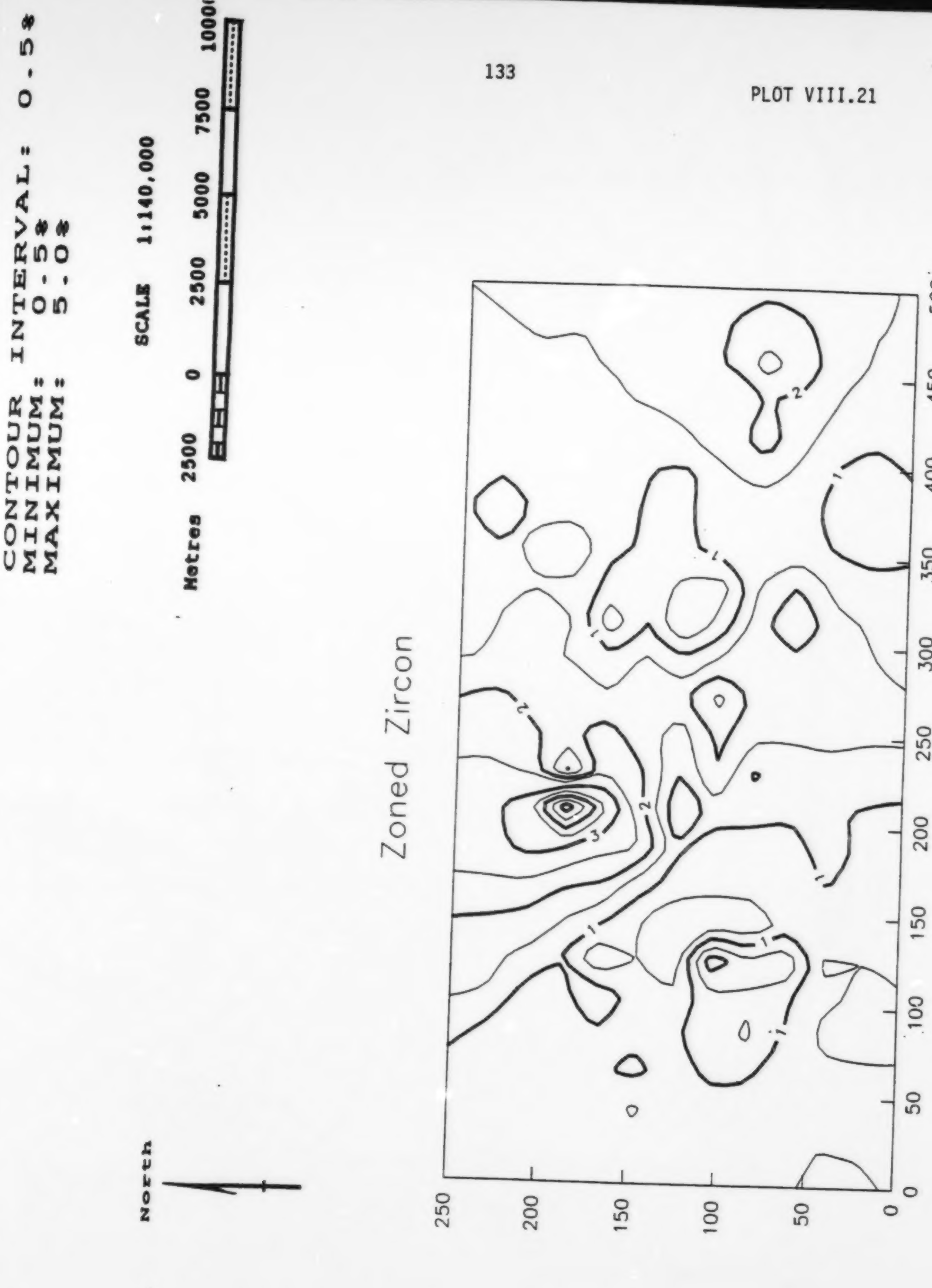
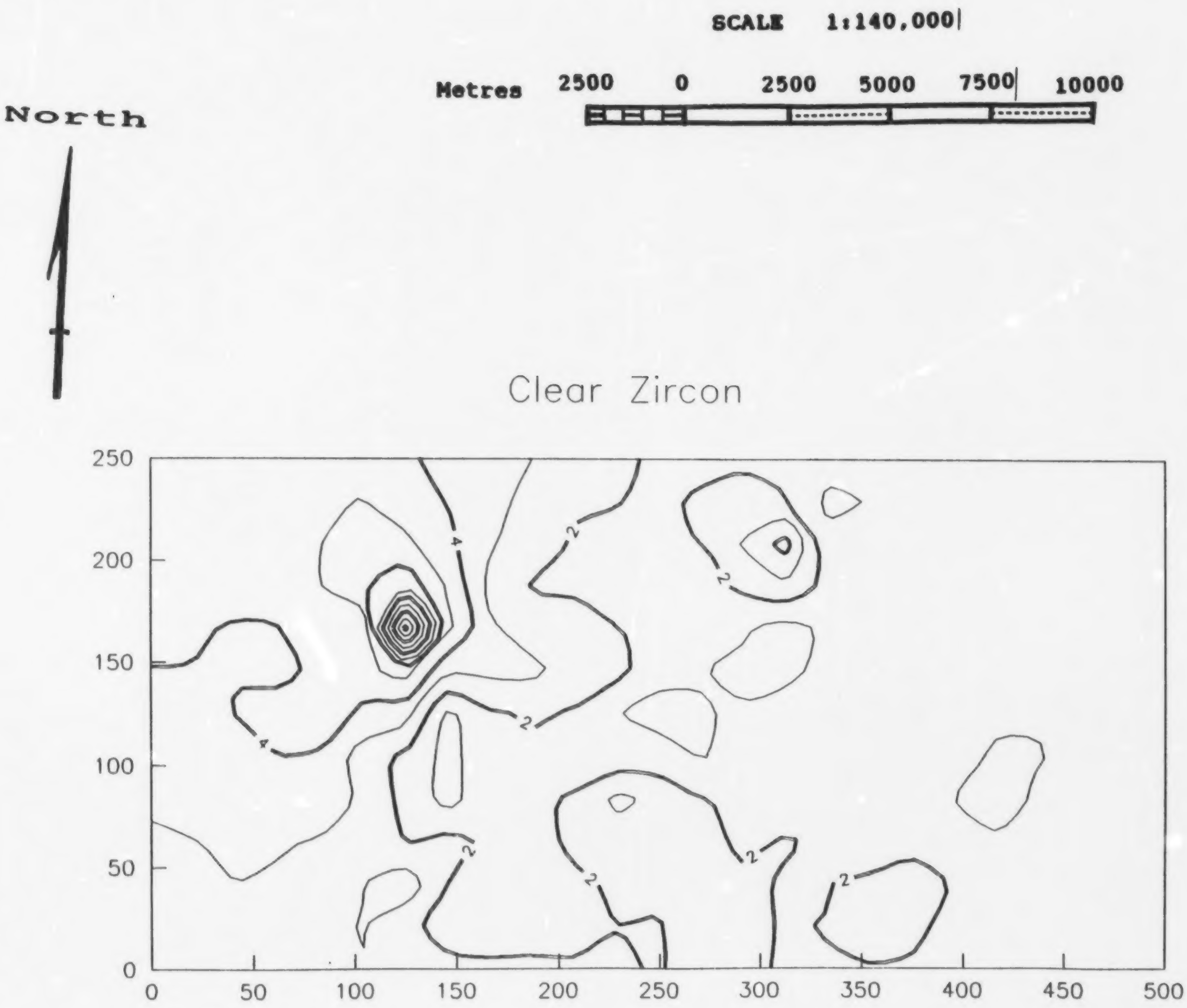


PLATE VII.19 Bornite with covellite alteration

PLOT VIII.21


CONTOUR INTERVAL: 0.5%
MINIMUM: 0.5%
MAXIMUM: 5.0%
SCALE 1:140,000
Metres 2500 0 2500 5000 7500 10000
North
Zoned Zircon
0
50
100
150
200
250
300
350
400
450
500
0
50
100
150
200
250
1
2
3

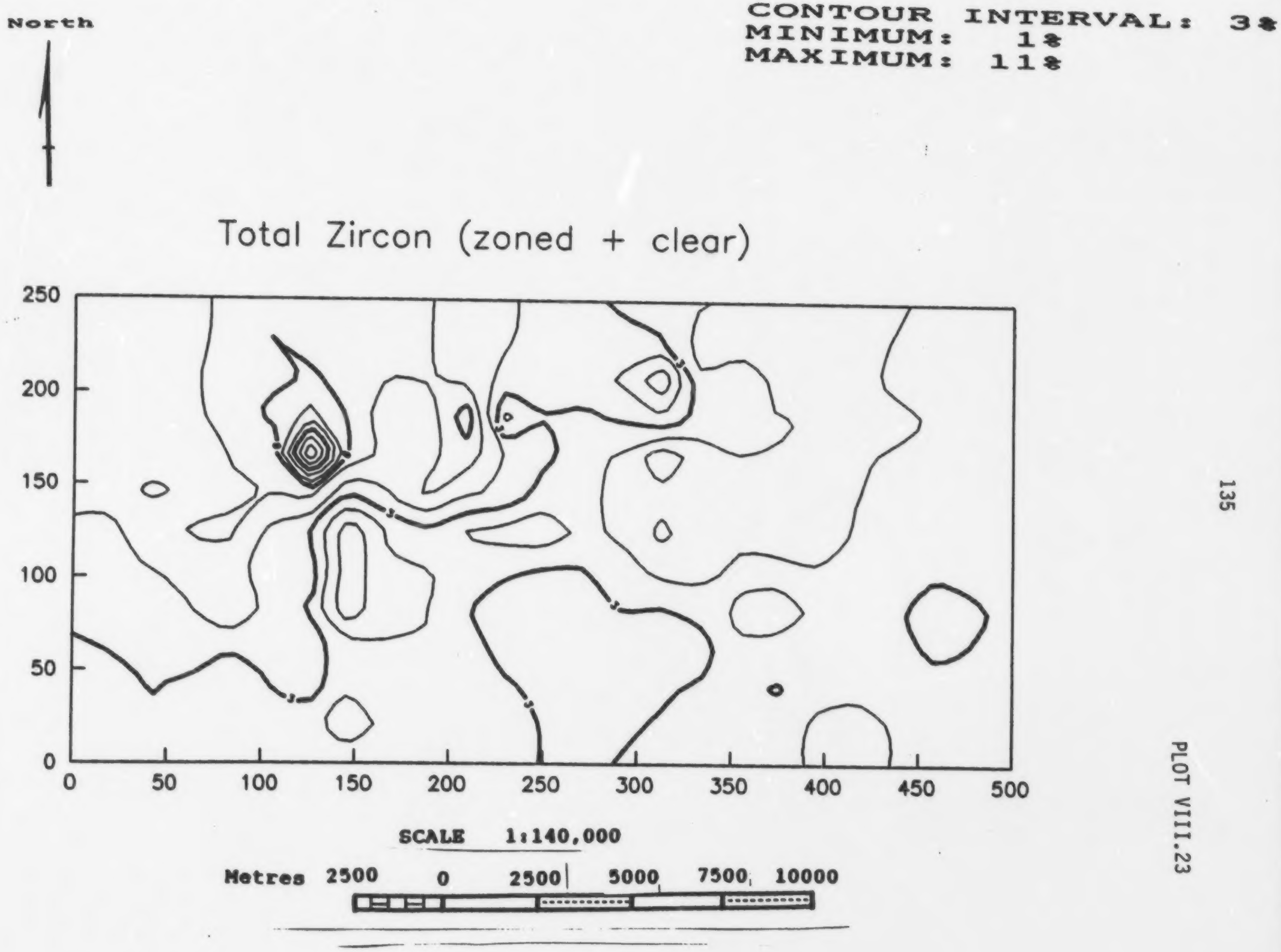
PLOT VIII.22



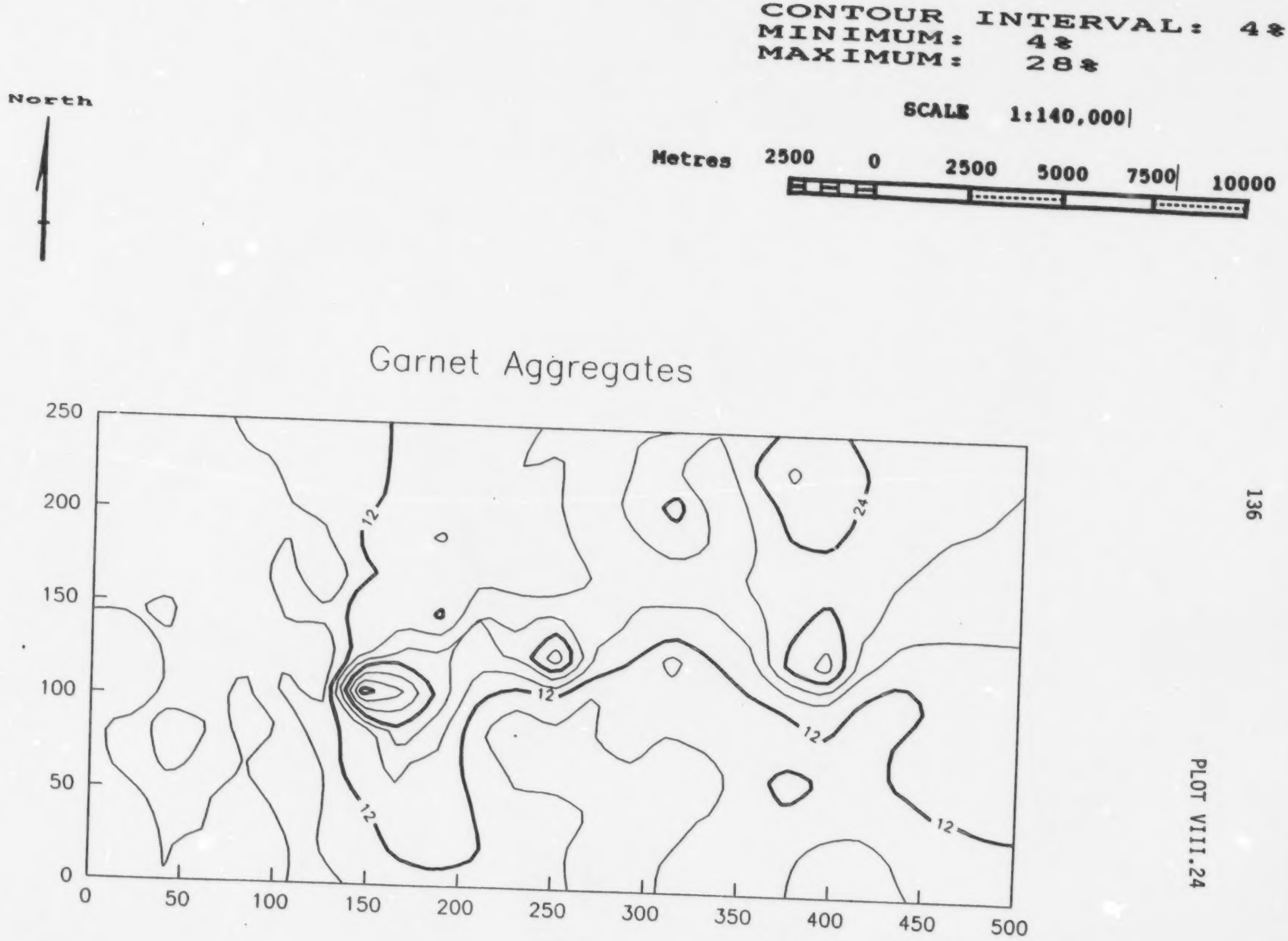
Clear Zircon

North
SCALE 1:140,000
Metres 2500 0 2500 5000 7500 10000
250
200
150
100
50
0
0
50
100
150
200
250
300
350
400
450
500
4
2

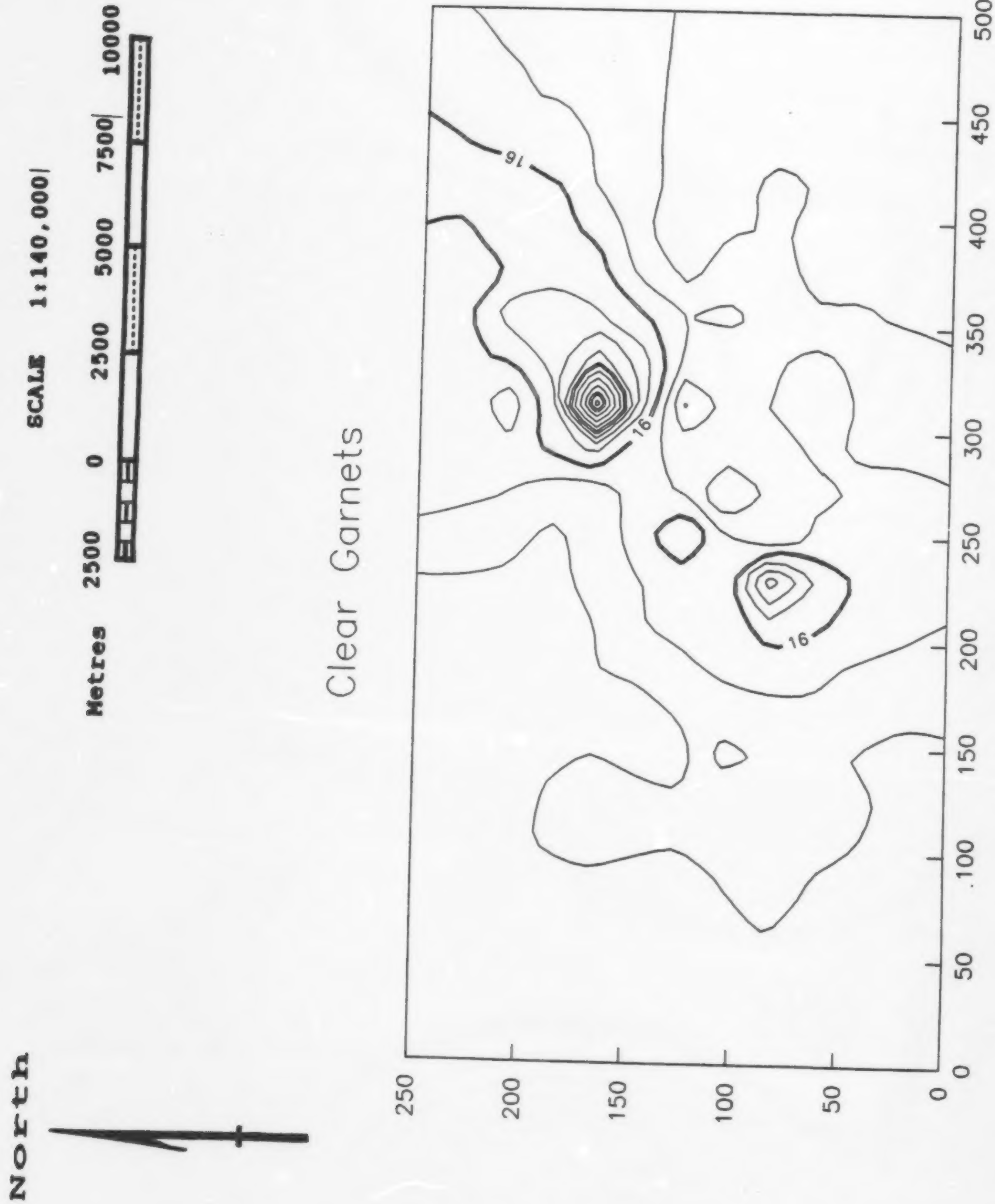
PLOT VIII.23


North
CONTOUR INTERVAL: 3%
MINIMUM: 1%
MAXIMUM: 11%
Total Zircon (zoned + clear)
250
200
150
100
50
0
0
50
100
150
200
250
300
350
400
450
500
3
SCALE 1:140,000
Metres 2500 0 2500 5000 7500 10000

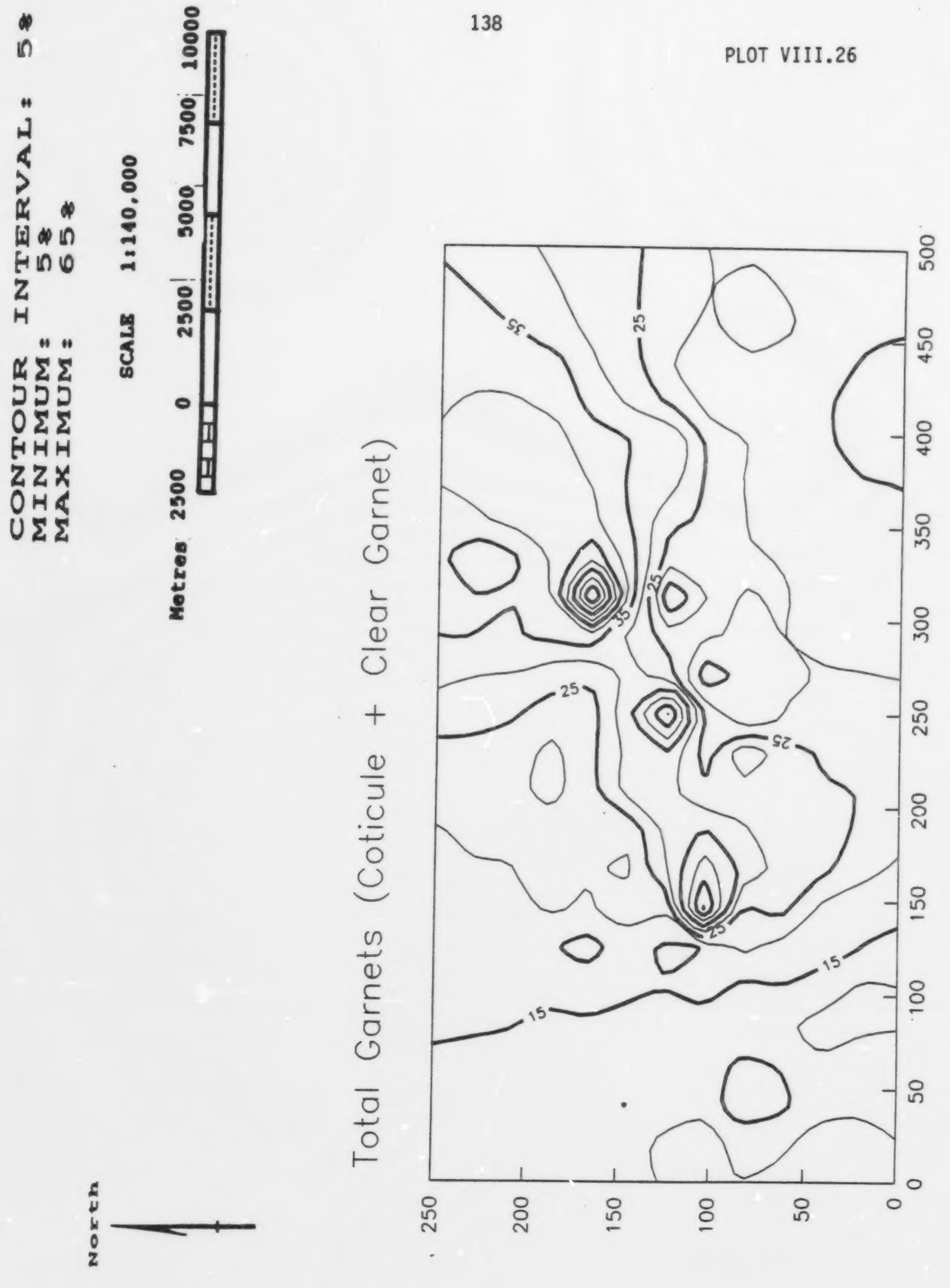
PLOT VIII.24


CONTOUR INTERVAL: 4%
MINIMUM: 4%
MAXIMUM: 28%
North
SCALE 1:140,000
Metres 2500 0 2500 5000 7500 10000
Garnet Aggregates
12
24
250
200
150
100
50
0
0
50
100
150
200
250
300
350
400
450
500

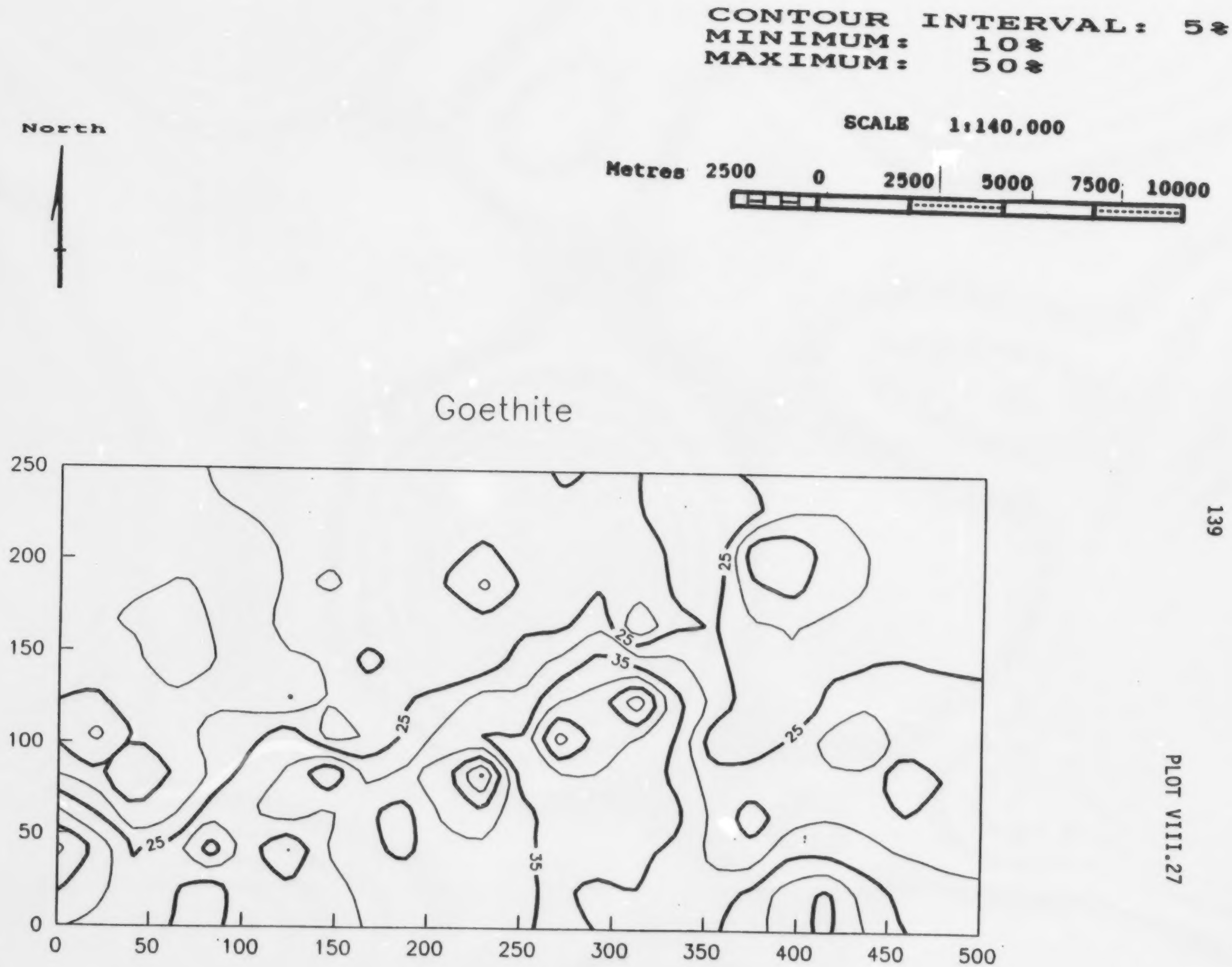
PLOT VIII.25


SCALE 1:140,000
Metres
2500
0
2500
5000
7500
10000
North
Clear Garnets
16
16
16
0
50
100
150
200
250
300
350
400
450
500
0
50
100
150
200
250

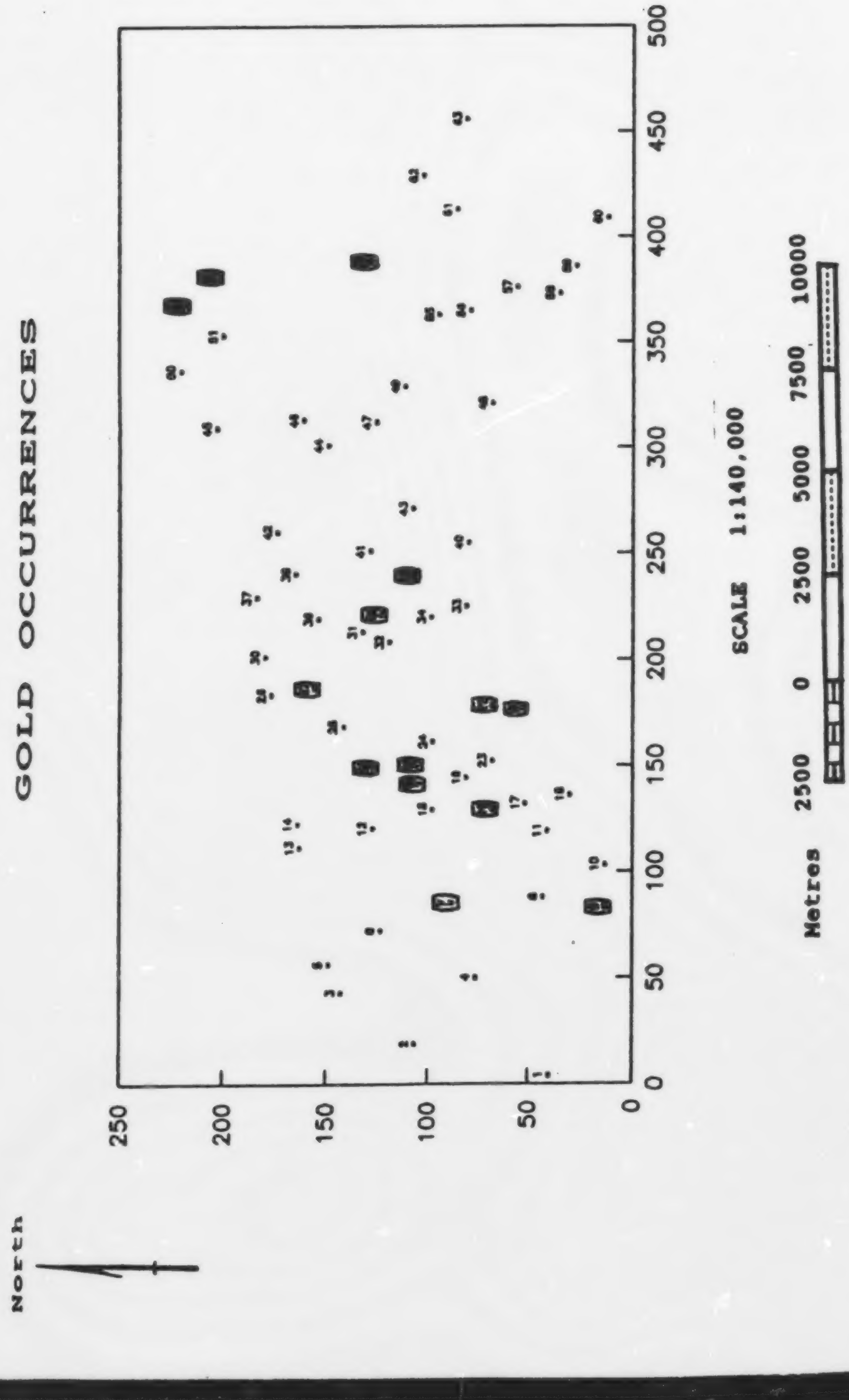
PLOT VIII.26


Total Garnets (Coticule + Clear Garnet)
CONTOUR INTERVAL: 5%
MINIMUM: 5%
MAXIMUM: 65%
SCALE 1:140,000
Metres 2500 0 2500 5000 7500 10000
North
15
25
35
0
50
100
150
200
250
300
350
400
450
500

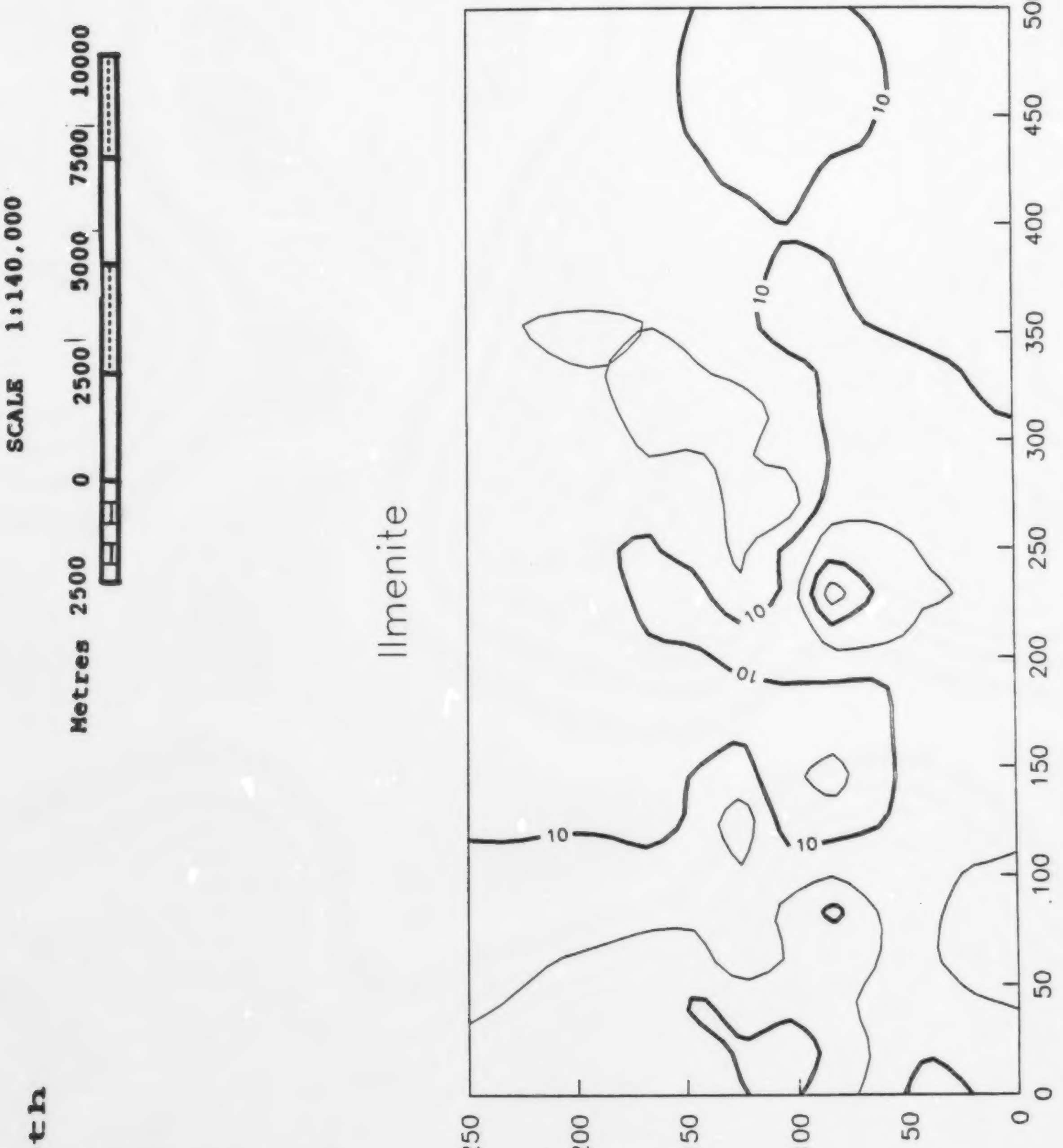
PLOT VIII.27


CONTOUR INTERVAL: 5%
MINIMUM: 10%
MAXIMUM: 50%
SCALE 1:140,000
Metres 2500 0 2500 5000 7500 10000
North
Goethite
25
35
25
25
25
35
25
0
50
100
150
200
250
300
350
400
450
500
0
50
100
150
200
250

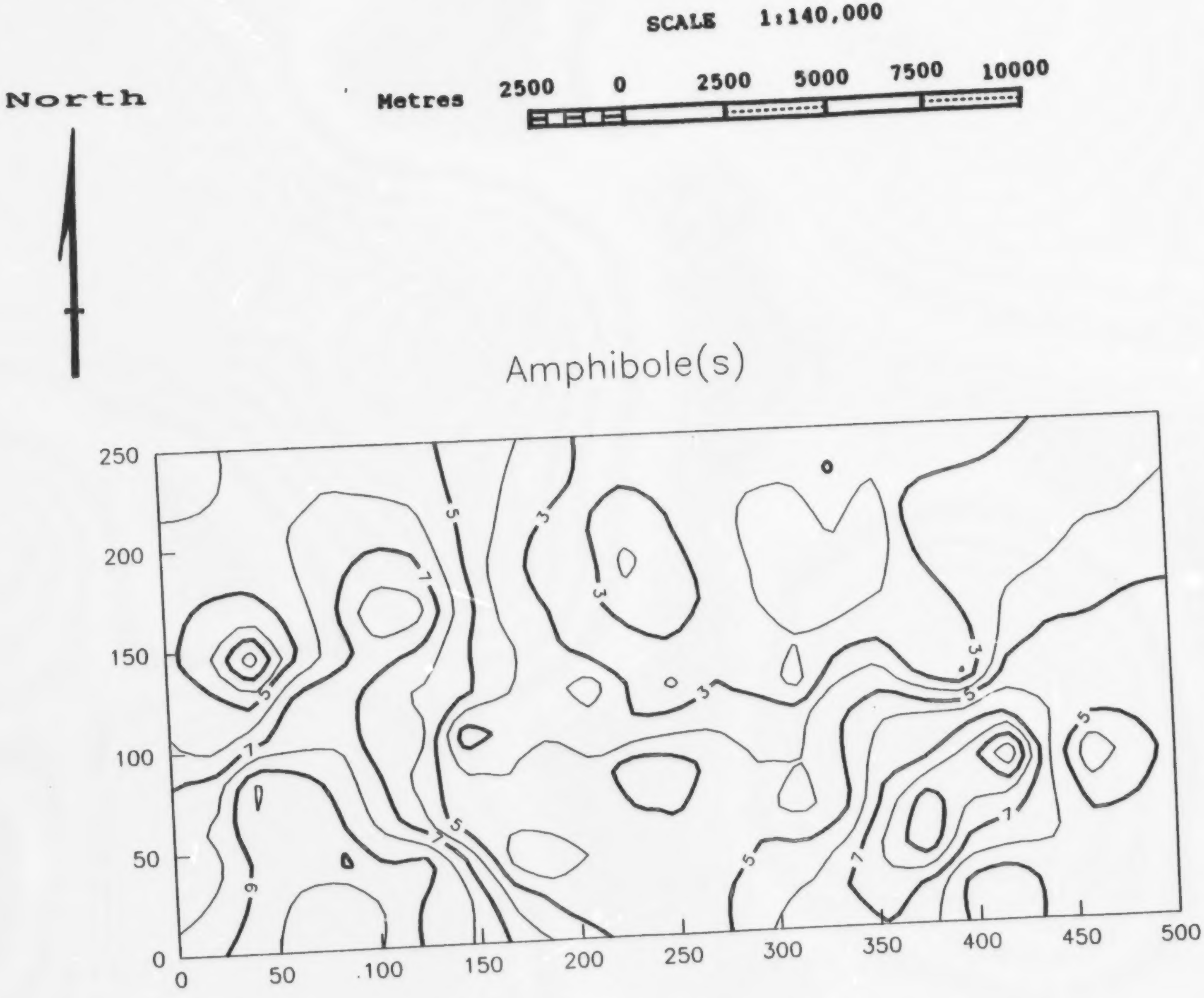
PLOT VIII.28


GOLD OCCURRENCES
0
50
100
150
200
250
300
350
400
450
500
0
50
100
150
200
250
SCALE 1:140,000
2500
0
2500
5000
7500
10000
Metres
North

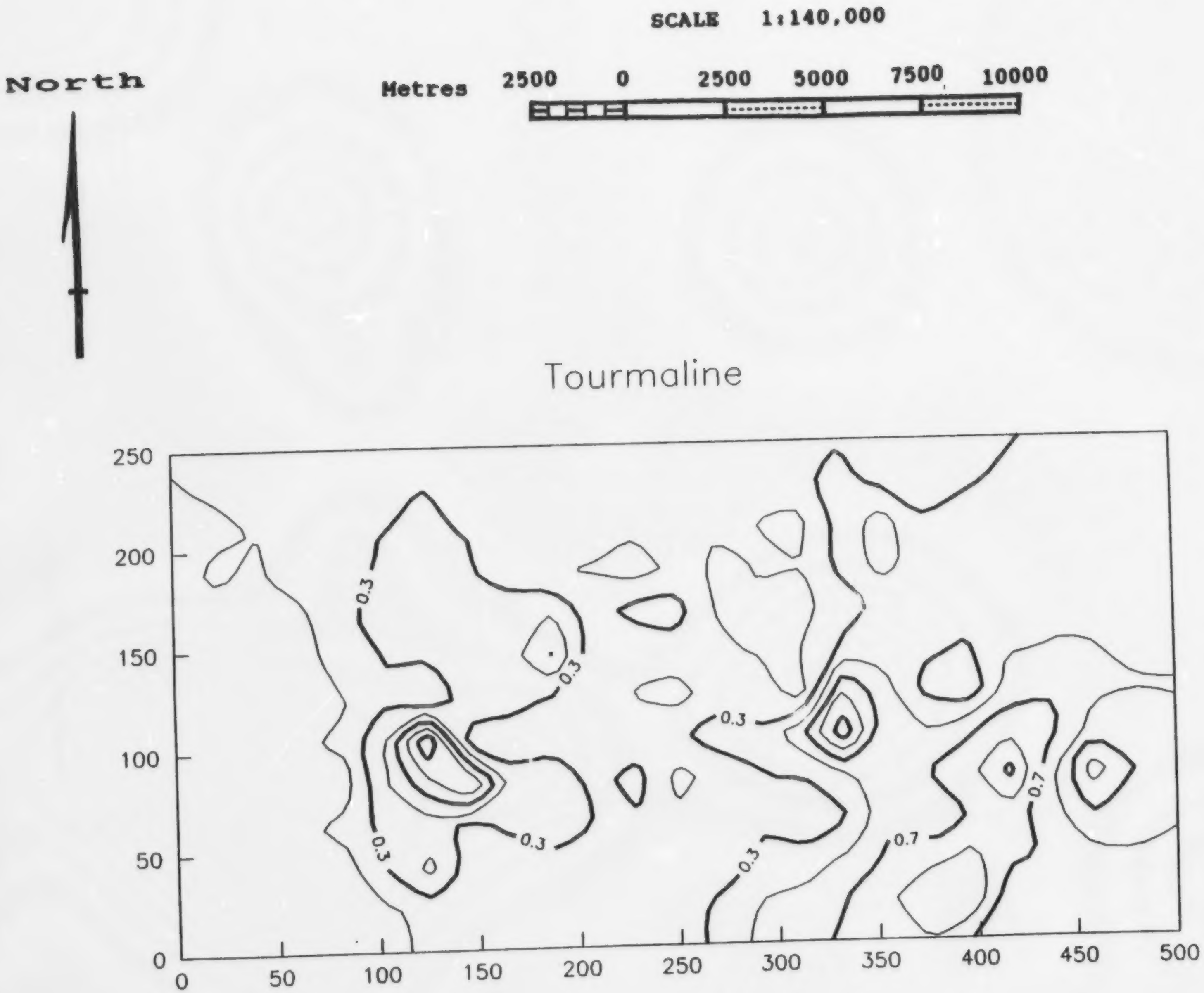
PLOT VIII.29


SCALE 1:140,000
Metres 2500 0 2500 5000 7500 10000
North
Ilmenite
10
10
10
10
10
10
10
0
50
100
150
200
250
300
350
400
450
500
0
50
100
150
200
250

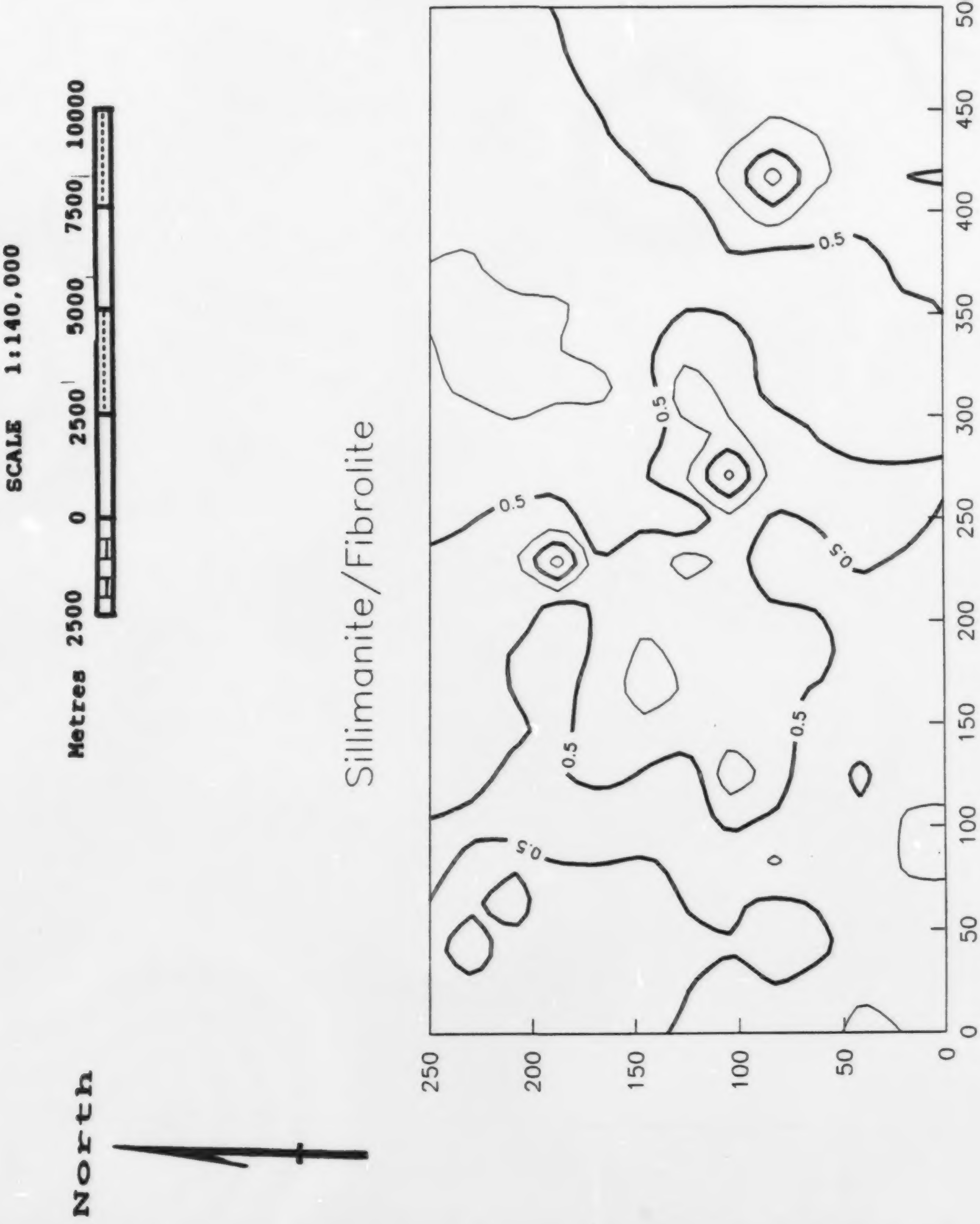
PLOT VIII.30


SCALE 1:140,000
North
Metres
2500
0
2500
5000
7500
10000
Amphibole(s)
250
200
150
100
50
0
0
50
100
150
200
250
300
350
400
450
500
3
5
7
6

PLOT VIII.31


North
SCALE 1:140,000
Metres
2500
0
2500
5000
7500
10000
Tourmaline
0.3
0.7
0
50
100
150
200
250
300
350
400
450
500

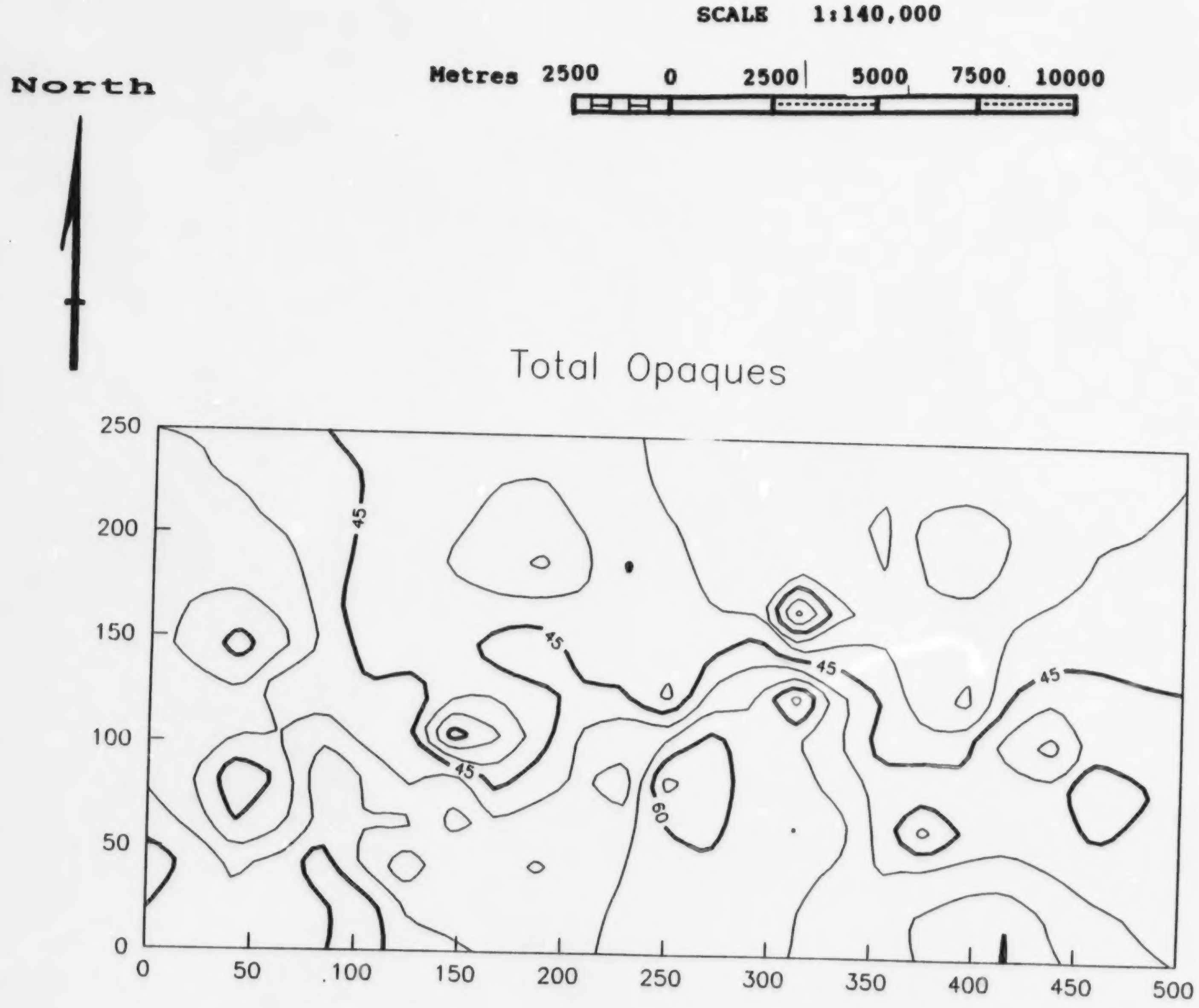
PLOT VIII.32



Sillimanite/Fibrolite

SCALE 1:140,000
Metres 2500 0 2500 5000 7500 10000
North
0.5
0
50
100
150
200
250
300
350
400
450
500

PLOR VIII.33


North
SCALE 1:140,000
Metres 2500 0 2500 5000 7500 10000
Total Opaques
45
45
45
45
45
60
0
50
100
150
200
250
0
50
100
150
200
250
300
350
400
450
500